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## THE OLDER WORKER

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WHILE it is true that modern war, the organized killing of our fellowmen and wholesale destruction of the products of human toil, can be waged most efficiently by men between the ages of 18 to 35, the industrial needs of this war have already demonstrated anew several important facts about the older industrial worker, facts well known, but forgotten or ignored in the plethora of peace-time manpower, and in the fog of a social philosophy according to which a life of leisure is heaven, and society must feed, clothe, and house all idle chicks whether or not these chicks can scratch. These facts are:

(1) The physiologic age of the worker is not synonymous with his chronologic age, owing to the individual variables in heredity, mode of living, accidents, and sequelae of disease.

(2) While most workers past fifty or sixty years of age have somewhat less physical strength and physical endurance, as well as some impairment of hearing and vision, these decreasing abilities may be compensated for in many forms of labor by the greater skill and experience and the decrease in youthful dissipation.

(3) By keeping in idleness older workers who can still perform useful labor we are not only wasting valuable human resources, but we are contributing to biologic parasitism in and degeneration

of human society. For man is no exception to the biological law that existence without effort, without struggle, impairs the species.

(4) By forced idleness of the increasing army of older workers in our midst we are forging a dangerously weak link in that large fraction of society, whose experience, wisdom and relative unselfishness could guide those with less experience and wisdom. For when a person is shunted out of the dynamic current of life, courage and incentive are at low tide.

(5) One element in the philosophy of organized or union labor, namely, equal hourly wage for all workers in each special trade, must share part of the blame for the past practice of discarding the older worker by the management of industry. Even though all workers are not equal in skill and efficiency, and in spite of the fact that the practice of organized labor tends to gear the rate of all workers to the slowest in the group, there comes a day when the older worker, in many given tasks can not keep pace even with the slowest and least efficient younger comrades. Economic management calls for dismissal of the older worker at that point. If wage in proportion to performance was permitted, the older worker could taper off in industry, just as the young apprentice works himself gradually up in skill, performance, and

remuneration. From my knowledge of human nature another destructive effect on morale, efficiency, and joy of living results from the practice of gearing the most efficient to the rate of performance of the least efficient. On that plan the ablest worker will seldom, if ever, experience the joy of performance according to his superior ability, nor the growth in skill commensurate with his ability. This is not only a waste of precious human resources, but tends to make lives humdrum, lives that could be enriched by the daily challenge and joy of more and better performance. For the ablest worker to be geared to mediocrity, to do less than his best, is bad psychology for the ablest people, and is, so far as I can see, of little or no aid to the less able fellow citizen or to society. I speak not without experience. I was a farm hand, and a labor union carpenter before I became a college student, and an investigator and a teacher in the medical sciences.

Under more primitive and biologic conditions of human life, as in life on the farm and in agriculture in general, work and responsibility of children and youth have their normal biologic upward curve, as is the case among all wild animals who have to scratch for their living. Under similar conditions of life, as on the farm, men and women past fifty, sixty or seventy years also find their niche of productive work, happy in the knowledge that they still have a part in the stream of life. Biologically, man grows in understanding and physical and mental efficiency from birth up to twenty-three or thirty years of age, when there is a plateau of efficiency for some twenty years, health being present. Then the reversal of the youth curve sets in, the gradual impairment of the physical, and considerably later even of memory and of mental efficiency. A civilization, a social or an economic sys-

tem, that discards men and women of fifty or sixty as no longer a link in the chain of human labor, as no longer productive physically and mentally, I say such a civilization, such social and economic systems, are thoroughly unbiologic, thoroughly wasteful and thoroughly cruel and inhuman to our fellowmen at the later decades of life. A man or a woman in modern industry, trained to do, and for twenty or thirty years having done only one such small thing as fitting a screw on a certain size nut for eight hours a day, may not be able to perform that mechanical feat at the sufficient rate when past fifty or sixty. But it is a terrible reflection on our education if such men and women can not do something else of value to society and to themselves. And it is certainly no indication of intelligent planning on the part of society if opportunities for such work are not afforded. In fact, tasks for which men and women past fifty, sixty and seventy are thoroughly capable lie all around us like mountains, but we do not see them. Social security for our aging population is all right in principle, but it should take the form of labor for which these people are capable and not the form of pay for doing nothing.

In industrial tasks calling for maximum performance of the entire machinery of the human body, the older worker by and large will be increasingly handicapped by the sequelae of accidents and disease, despite all efforts of accident prevention, and the growing knowledge and skill in medicine. Apart from, and in addition to these factors, what are the inevitable and unavoidable aging changes of man rendering him less fit, if not unfit to labor? When and how speedily do these aging changes come on in the individual? Do these aging changes or impairments constitute a bar from all useful labor? Can industry be

organized so as to make fair and adequate use of men and women handicapped by age alone? Is there no alternative to the relegation of men and women past fifty, sixty, or seventy years of age to the scrap-heap of idleness and the dole, to parasitism, and charity? All age changes come on gradually. Those body changes with age involving the strength and endurance of the skeletal neuromuscular mechanism, and with the senses of hearing and vision are probably the most significant for the industrial worker, but it must also be kept in mind that these systems are all dependent on a good diet, a good gut, good blood, good kidneys, and good lungs. The human body is a machine. Any weak link tends to impair all the other links. Some age impairments appear as early as the third decade. If all industrial labor were physically as exacting as prize fighting, marathon running, or professional football, nearly all workers would be retired at thirty-five years of age.

Progressive age changes not as yet shown to be due to specific diseases are: gradual tissue desiccation; gradual retardation of cell division, capacity of cell growth and tissue repair; gradual retardation in the rate of tissue oxidation (lowering of the B.M.R.); cellular atrophy, degeneration, increased cell pigmentation and fatty infiltration; gradual decrease in tissue elasticity and degenerative changes in the elastic connective tissue; decreased speed, strength and endurance of skeletal neuromuscular reactions; decreased strength of skeletal muscle; progressive degeneration and atrophy of the nervous system, impaired vision, hearing, attention, memory and mental endurance.

*The Neuroskeletal System.* The gradual slowing and weakening of reflexes and general body activity in the aging mammal is so obvious as to be well known both to physicians and laymen. De-

creased functional capacity, both in the nervous tissues and the skeletal muscular tissue, seems to be at the base of this gradual decline. Actual atrophy of the Purkinje cells of the cerebellum has been described in the aged and, since this part of the nervous system is seriously concerned with skeletal muscle tone and coordination of skeletal muscle contractions, it may be a factor in the growing muscular weakness of old people, irrespective of the cause or causes of this atrophy in the cerebellum.

As regards the cerebrum of aged people, general atrophy has been described especially in the frontal and occipital lobes, and actual disappearance of cells in some of the layers of the cerebral cortex, as well as pigmentation and fat infiltration of the nerve cells and actual hyperplasia of the neuroglia cells. Similar degenerative changes with age occur in the spinal cord; that is, atrophic pigmentation, actual loss of cells and degeneration of the axones of many ventral horn cells. In the case of the brain, thickening of the meninges occurs with advancing age, but it is difficult to see how this in any way should interfere with nervous action or nervous function.

Recent investigations appear to demonstrate a very gradual but significant decrease in the myelinated fibers of the dorsal nerve roots with advancing age. This must be secondary to an atrophy and death of spinal ganglion cells and is probably the basis of the reduction in cutaneous and protopathic sensibility of aged people. The sense of pain seems to be the least affected by aging. In view of such evidence of atrophic and degenerative changes in the central and peripheral nervous system, irrespective of the primary cause or causes of these changes, it is not surprising that neuromuscular weakness, slowing of the reaction time, decreased capacity to learn, etc., are part and parcel of the physiolog-

ogy of aging. The speed of learning seems indeed to decrease gradually in man from the fourth decade on. But this handicap of the aged is on the whole more than made up for in some individuals by their greater speed of correlation and evaluation of the new experience.

There is very little evidence of aging changes in smooth muscle, which seems on the whole to retain its normal histologic character into advanced old age. The diminished tone in smooth muscle, as may be seen in the blood vessels in the gut and the smooth muscles of the skin and other structures in old people, may be secondary to the impairment in the nervous system, indicated above. But not all the impairment of body motility with age can be ascribed to degenerative changes in the nervous system itself, because the striated skeletal muscle system shows fatty infiltration and brown atrophy with advancing age. The strength of the biceps at the sixth decade of life is only about fifty per cent. of that at the age of twenty-five to thirty. The trunk muscles decline in power somewhat slower. However, the recent investigation by Kubo (1938) reports little evidence of decrease in muscle strength and endurance in people that would ordinarily be called old, that is, people seventy to ninety years of age. This is just another illustration of the individual variations in the chronologic age appearance of the aging processes. There is some increase in connective tissue and elastic fibers in the skeletal muscle of old people and there is clear evidence of desiccation, that is, decrease in intracellular fluid. But in this respect the skeletal muscle of the aged falls in line with all the other tissues of the body.

*Vision and Hearing.* Because of the accessibility of the organs themselves and the availability of quantitative tests of

functions, we have more accurate information regarding the aging changes in the physiology of the eye and the physiology of the ear than in most of the other systems of the human body. In the case of vision, there is a gradual decrease in visual acuity (central vision), a gradual narrowing of the visual field, as well as a slowing of the dark adaptation (peripheral vision), and a gradually higher threshold for light stimulation for man past the fourth decade. The narrowing of the visual field is probably due to the actual degeneration of the nerve cells (cones), starting in the periphery of the retina. We are not yet in a position to say whether these visual impairments occur independent of, or are secondary to, impaired retinal circulation. It is equally well known that the incidence of cataract increases with aging, irrespective of whether or not the tendency to cataract formation is hereditary. Arterial sclerosis would undoubtedly accelerate any such hereditary weakness, and so would certain faulty diets and certain endocrine and other metabolic disorders. The gradual decrease of the elasticity of the lens is another well-known and accurately measured phenomenon of aging man, with the exception that diminution in lens elasticity actually starts in childhood and practically all lens elasticity is lost before sixty years of age. The lens continues to grow at the periphery (vertex), and thus approaches closer and closer to the cornea with advancing years. At the same time, the material at the center of the lens becomes more dense. Both of these factors, and the lens swelling from increased water content, are responsible for the well-known phenomenon of so-called "second sight" of people sixty years of age and beyond. This lens change tends to counteract the presbyopia, or impairment of accommodation, due to the loss of lens elasticity. Other age changes that may contribute

to the gradual impairment of vision with age are diminished translucency of the cornea and of the vitreous humor. It need not be pointed out that the retina, being actually a lobe of the brain, is necessarily as seriously impaired by local vascular pathology as is any other part of the brain. However, because of the accessibility of the retinal vessels to direct inspection, we have probably earlier factual information regarding such pathology in the retina than we have in most of the other deep organs of the body.

*Hearing.* From the age of about twenty on, there is a gradual loss of acuity to all tones, but the loss of sensitivity is greater to the high tones. This deterioration of hearing is somewhat greater in the male, but the degree of retrogression is not predictable in chronologic age, as some people at eighty have no greater auditory impairment than other normal people at fifty. This impairment of auditory acuity is present even when tested by bone conduction. The cause for this decline in auditory acuity appears to be a gradual but distinct atrophy of the nerve cells in the basal coil of the cochlea. But anemia, due to incipient arterial sclerosis, may also be a factor, since in experimental anoxia the perception of the high tones goes out first.

In the light of all these facts, one would expect that intellectual capacity should decline parallel with neuromuscular strength and endurance. According to all existing evidence, this is not the case. This exception is probably due to the significant role of experience, especially in the case of complex intellectual problems.

*The diet of the older worker.* While we do not know what may be the optimum diet for optimum efficiency for any age, we do know enough to say with certainty that the older worker will keep

most fit by eating enough good food to avoid underweight, and avoid eating so much food that he or she becomes obese. Life insurance statistics show clearly that marked underweight, as well as marked obesity, shorten the life span. Common experience demonstrates that both impair physical endurance and performance. It is not difficult to understand why ingestion of food to the point of obesity is injurious to people with reduced factors of safety in the matter of insulin, pancreas, sugar and fat metabolism. Such dietary excesses damage by overwork already impaired mechanisms. But in the absence of diabetes, actual or incipient, why does obesity, maintained for years, initiate or aggravate cardiovascular, renal, and other disorders that shorten the life span? While the answer to these questions is being sought by experiments and accurate observation on mice and men, prevention of obesity in all workers past thirty appears to be a prophylactic imperative, a *must*.

From time to time financially fortunate and humane fellow citizens provide funds for "old peoples homes." I hope that some financially fortunate, humane, and farsighted fellow citizens will soon provide the National Research Council with a fund of \$1,000,000 to be used towards learning *what is the optimum diet for old people*: old workers in industry, as well as those in old peoples homes. It should be quite clear to all informed people that normal aging strikes no man with suddenness of an acute disease. We are not worth 100 per cent., industrially, today, and worth zero tomorrow on our sixty-fifth or seventieth birthday. We grow old and inefficient, just as we grow up and efficient, over the years. We have discovered that useful work can be performed by people with disabilities more serious than those of normal aging, such as the blind, the deaf, the mute,

people minus a hand, an arm, a leg, or both legs. We readily admit that useful work suitable to the gradually aging worker is less readily provided in industry than on the farm. But it can be done, it has been done, it is being done even in industry. Such an experiment by the Dodge Division of the General Motors Corporation in Detroit is described in some detail in *Forbes' Magazine* for November, 1942 by Don Wharton. This experiment seems more significant as it was well under way (1934) before the present war, and hence, not carried financially by the present billions of federal war appropriations. The ninety-nine workers in the "Old Man's Division" of the Dodge plant average sixty-six years in age and some of them are past eighty. In the farflung Ford industries a more extensive and commendable employment of people handicapped by age, and by the sequelae of disease and accidents, appears to be an established and a feasible practice (*Saturday Evening Post*, Feb. 6, p. 16, 1943). Says Edsel Ford: "No man is hopeless or helpless as long as he has the will to do and his fellow men will give him a helping hand. Courage is not a matter of age or physical conditions." But the fact that all of these workers receive the same pay (93 cents an hour) makes me think that the department is not run on a strict economic basis, that the excess costs, if any, are charged against all the workers in that industry, or added in the price of the product, a practice not uncommon, and possibly justified in the better morale of the older worker. The general formula relating work to remuneration seems simple:

A. The younger worker: Physical strength and endurance growing, but not at adult par; skill and experience growing, but not at adult par—less than adult performance and pay.

B. The adult worker: Strength and endurance at maximum; experience and

skill near or at maximum—maximum performance and pay.

C. The older worker: Physical strength and endurance receding, experience and skill at par—generally less than adult performance and therefore less pay.

I never could understand, I do not now understand, how industry as such can practice charity. Monies so devoted must, by necessity be deducted from wages, salaries and dividends to stockholders, or else the cost added to the cost of the product, in which case the charity is given, to be sure, without their knowledge by the consumers of the industry's product. Some day man may achieve sufficient stoicism to face with equanimity the fact that charity and doles are for the children and the sick, not for the aged, unless incapacitated by age.

If what I so far said squares with facts, reason, and wisdom, as well as with our conception of justice, we might expect educational institutions to be ahead of industry in the elimination of waste of the older workers. But this is not so. In general, there is full salary and duties of college and university men up to sixty-five and seventy, and then abrupt unemployment, on assumed total incapacity. Two factors are probably mainly responsible for this waste: (1) the younger generation in a hurry, and (2) the older generation so ignorant of biology that it can not see the justice of reduced pay for reduced capacity and performance. One of our large state universities recently recalled as dean of its graduate school a man now seventy-seven, whom the same university retired from that position nearly ten years ago. It is not probable that this university dean is to-day more capable than he was ten years ago. It seems more probable that this university wasted a valuable human resource for ten years.

According to the United States Census, the number of people past sixty-five years of age in our population has in-

creased during the last ninety years from 2.6 per cent. to 6.8 per cent. If this trend continues, and I think this is assured by more of science and the better art in medicine, fifty years hence about fifteen out of every hundred people will be over sixty-five years old. I think we can add that, by and large, this army of older people fifty years hence will be even better qualified for useful work than are the people of the same age to-day. Thanks to more science and better art in to-day's medicine our larger aged army of 1940 is less decrepit than was our smaller army of sixty-five-year-olds a hundred years ago. It is sheer waste, bad biology, and gross injustice all around to feed, house, and clothe this army of idleness. Old age pension is not the answer. The dole is not the answer. The only answer is useful work for pay, plus sickness and accident insurance. When aging has rendered us incapacitated for useful work, we are truly sick, and sickness insurance should meet our needs. I think I am discussing important principles, not arguing about names, not fighting windmills. Still, it must be admitted that at sixty-eight some people fail to recognize their own delusions. I think that useful work is a privilege and a blessing, not a curse. It is also a biologic and social duty as long as we can carry on. Because the probability of less

elastic arteries and less cardiac reserves, not to mention less strength in the skeletal muscles, the worker past sixty should, as a rule, not be put at tasks calling for the physical power that a worker, age twenty to forty, may deliver with safety. Moderation in all things, and a thorough medical check up twice a year will aid us in keeping fit to carry on. There is the prevailing view that quitting useful work before the infirmities of old age and specific disease compel it, hastens the age decline and brings on death sooner. It is difficult to check this view by adequate controls. So far as I know, this view is based on conspicuous instances, forgetting the exceptions. But to the extent that idleness decreases the zest of living, and unhappiness and depressing mental states actually impair some of our body machinery, it may be true; especially if the pleasure from good food is still strong, for in that case injurious overeating is likely to become the rule. I dream of a to-morrow when our millions of men and women, well past the chronologic three score will say, with Albert J. McCray, age seventy-one, now running a drill press at a Douglas Aircraft plant, "I'd rather have a job than a pension any time" (*Time*, Dec. 14, 1942) for that spirit helps to keep the older worker young, and aids in making America stronger.

# ARTIFICIAL RADIOACTIVITY AND THE COMPLETION OF THE PERIODIC SYSTEM OF THE ELEMENTS

By Dr. E. SEGRÈ

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EVERY time that some fundamental advance has been made in one of the physical sciences, it has almost immediately brought fruits in neighboring fields, revealing that close interdependence between various branches of the sciences which is one of their most characteristic features, even in times of ever-increasing specialization.

The interaction between physics and chemistry has always been particularly strong, and one of the forms it has taken is that of new chemical discoveries being brought forward by the application of some newly developed physical method of investigation to chemical problems. Thus, we may consider the most fundamental and classical problem, that of knowing all the elements. The history of this quest is a most fascinating one and in the early days of scientific chemistry could almost be identified with the history of chemistry itself.<sup>1</sup>

When the impetus of the newly developed scientific analytical chemistry had spent itself around the middle of the nineteenth century, about sixty elements had been discovered and most of the minerals offered by nature had gone through the mills of chemical analysis. At the same time the genius of Mendeleef (1869) was laying the foundation for a systematic interpretation of the discoveries made and gave hints as to the directions in which the search could be prosecuted. However, it was clear that the missing elements must be either very rare in nature or, for some reason, very difficult to isolate (rare earths), so that

<sup>1</sup> See *e.g.*, M. Weeks, "The Discovery of the Elements."

new and more powerful tools were necessary to make substantial progress. It happened that in 1860 this tool was most luckily found by Bunsen and Kirchhoff in the application to chemical problems of the newly developed spectroscope; and the fruits were copious and immediate (discovery of rubidium and cesium first, later many other elements). The spectroscope became a most useful tool for the further progress of the knowledge of the elements, allowing us to find them even on the sun, when no terrestrial sources were known (Helium, Lockyer). However, after a while even the optical spectroscope had exhausted its almost miraculous powers and the utmost refinements of old and well-known techniques had reached their limits, after the discovery of the noble gases and the partial unraveling of the complex of the rare earths. But Mendeleef's table showed merciless white spaces still to be filled by the scientist's ingenuity. Certainly if it had been known how rare are elements like polonium on the earth's crust, the quest would have been given up as hopeless.

It was the investigation of a strange physical phenomenon that, around the turn of the century, gave the most sensitive analytical method known to date, and at the same time started the greatest revolution in the foundations of chemistry since the time of Lavoisier, Dalton and Avogadro. Some of the "eternal and immutable atoms" of classical chemistry were shown to undergo spontaneous transformations, uncontrollable by man and dominated by the law of chance. By catching them in the intermediate states

of their evolution, first the Curies, and later Rutherford, Soddy, Hahn and others, were able to add to the known ones many other chemical species, the most notable being radium and polonium. Their ultrasensitive methods are, however, able to reveal only "living" atoms, or, more scientifically, unstable atoms, because they are based upon the detection of the radiations given out by the atoms at the moment of transformation. Unstable atoms with minor exceptions are found in nature only among the heaviest, most complex atoms and hence the discoveries made with the help of natural radioactivity were only of elements heavier than lead.

The laws of radioactive decay assign to each atom of a given kind a constant, finite probability of exploding in a given time interval (decay constant). This probability may be very small as in uranium ( $5 \times 10^{-18}$  per second), or very high as in  $UX_2$  ( $1.0 \times 10^{-2}$  per second). The reciprocal of the decay constant is called mean life. However, if a substance B originates through any number of transformations from a substance A having a smaller decay constant, after having waited a sufficient length of time, a situation arises in which, in a mixture of the two, the number of A atoms exploding per unit time is equal to that of the B atoms exploding per unit time. Such a condition is called radioactive equilibrium. The number of explosions in A and B per unit time, if the two substances are in radioactive equilibrium, is the same, but the numbers of atoms of A and B present may be tremendously different: as a matter of fact, the ratio of the numbers of A atoms to B atoms is equal to the reciprocal of the ratio of the decay constants. It is easy to calculate, for example, that for one gram of uranium we have in radioactive equilibrium with it  $5.0 \times 10^{-16}$  gram of  $UX_2$ . This amount is extremely minute, but if we use for detecting the substance a device that counts not the atoms, but the ex-

ploding atoms,  $5 \times 10^{-16}$  gram of  $UX_2$  will be just as easy to detect as one gram of uranium. From these considerations it follows that the radioactive methods may have a tremendous sensitivity compared with any other one, provided the substance to be investigated has a large decay constant.

It is also clear that a short-lived substance may be present in nature only if it is in radioactive equilibrium with one that has a very long life; so that a large fraction of the latter's atoms, present at the formation of the earth, has had the possibility of surviving. This means that the smallest mean life admissible is in the order of  $10^9$  years. Shorter lived substances, if not in equilibrium with a long-life parent substance, have practically disappeared. The ordinary stable elements are the final fossils of all these atomic evolutionary processes. They were apparently dead forever until man found, a few years ago, a new way of resuscitating them and starting some new transformations in them, certainly less rich than the natural ones, but nevertheless of great scientific interest.

Natural radioactivity thus helped to fill the gaps in the periodic system among the heaviest elements, but some of the blanks shown by Mendeleef's table were among the light elements; and besides these, there was a region of the periodic table, that of the rare earths, where even that most powerful heuristic tool could not make unequivocal predictions even about the number of missing elements. Again a new fundamental discovery in physics gave the key to the enigma. In 1912, Moseley, using the newly discovered x-ray spectroscope, found a regularity in the x-ray spectra of the elements which allowed him to read the atomic number, or the ordinal number of the element in the periodic system, directly from the spectrum. It was then easy to find out which elements were still missing. The empty places had the numbers 43, 61, 72, 75, 85, 87 and 91. These numbers are

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Natural radioactivity thus helped to fill the gaps in the periodic system among the heaviest elements, but some of the blanks shown by Mendeleef's table were among the light elements; and besides these, there was a region of the periodic table, that of the rare earths, where even that most powerful heuristic tool could not make unequivocal predictions even about the number of missing elements. Again a new fundamental discovery in physics gave the key to the enigma. In 1912, Moseley, using the newly discovered x-ray spectroscopy, found a regularity in the x-ray spectra of the elements which allowed him to read the atomic number, or the ordinal number of the element in the periodic system, directly from the spectrum. It was then easy to find out which elements were still missing. The empty places had the numbers 43, 61, 72, 75, 85, 87 and 91. These numbers are

simply the positive charge of the "sun" in the planetary atom, assuming as unit charge the charge of the electron, and each completely determines the chemical properties of an atomic species.

Elements 91, protoactinium, and 87, ekacesium, are among the very heavy ones and were found in nature in the radioactive families by Hahn and Miss Perey respectively. Elements 72 (hafnium) and 75 (rhenium) are also found in nature and are stable; their detection and isolation was achieved by Hevesy and Coster (72) and by I. and W. Noddack (75) in the twenties. Especially in the case of element 72, the discovery was guided by the great progress that had been made in the theoretical unraveling of the atoms, thus making possible a prediction of its properties, on which the semi-empirical table of Mendeleeef gave uncertain information. Its name hafnium, from Copenhagen, was chosen in homage to that center of research where Bohr and his associates played such a large part in developing the modern atomic physics. The chief analytical tool in both investigations was the x-ray spectroscope.

After these discoveries, the only elements left were 43, 61, 85, and an intensive quest has been made for them in *natural* products. Many times success has been announced, but subsequent investigations have always failed to confirm the discoveries claimed. The probable reason for this situation is that according to our present knowledge of the atomic nucleus such elements are unstable and could be found in nature only in the relatively unlikely case that they should possess an extremely long half life. The prediction of the instability of such nuclei is based upon a large amount of empirical material and a plausible theoretical interpretation of the same, and they are the only elements deemed unstable by the rules of Mat-  
tauch.<sup>2</sup>

<sup>2</sup> See e.g., H. Jensen, *Naturwiss.*, 26: 381, 1938.

Hence until the discovery of artificial nuclear transmutation it was hopeless, although it was not known to be so, to look for the missing elements in the natural ores, their only terrestrial source. The situation changed entirely with the advent of artificial transmutation, because it then became possible to *manufacture* the element one wanted to study. A vast amount of experimental material on artificial radioactivity which has been rapidly accumulated, systematized, and given a theoretical interpretation between 1934 and the present, has made it easy to predict what type of transmutation occurs under a given kind of bombardment. Generally the prediction is not unique, but only a few alternatives are left. Thus by slow neutron bombardment one almost always has the transmutation into a heavier isotope of the same atomic number; by deuteron bombardment the atomic number is changed by +1, -1, or 0; by alpha particle bombardment the atomic number is increased by one or two units, etc.

If, for example, we bombard element 42, molybdenum, with deuterons, we can reasonably expect that some isotopes of element 43 will be found; and if they are radioactive we will be able to detect even the extremely minute amounts formed by this method. The question arises, however, as to how we are going to be sure that the radioactivity observed is due to element 43 and not to some other substance, for example, a radioactive isotope of molybdenum, formed in the bombardment. The answer is very easy if we have a stable isotope of the newly produced substance, because then if we add a little of it to our radioactive substance and perform the usual procedures of chemical analysis, we shall observe that the radioactivity sticks together quantitatively with the stable isotope of the radioactive substance, and no chemical operations can ever separate it. To be sure, this is only a negative proof because, strictly speaking, one can not carry out all pos-

sible chemical reactions with a given substance, and one may miss just the important ones. That this can actually happen is borne out by the almost incredible tale of the transuranic elements, and especially of element 93 where, by the incorrect application of these principles, many mistakes were made.<sup>3</sup> On the other hand if two substances can be chemically separated by analytical methods they certainly are not isotopic.

The situation is more complicated in the case of a new element, and especially of the artificial ones, because the amounts available are then so extremely minute as to be invisible and unweighable. The detection occurs through the radioactivity, but it is impossible to carry on most of the chemical operations in the ordinary way. Thus, for example, precipitation and filtration of the pure substance are well nigh impossible. Also, serious doubts may be entertained as to whether the behavior of a substance at such extreme dilutions is the same as for ordinary quantities. This whole complex of problems is not new: as a matter of fact, it arose in the early days of radioactivity, and a whole branch of chemistry, radioactive chemistry, is devoted to its solution.

We now have a whole series of semi-empirical rules by which we can reasonably predict, from the behavior of a radioactive isotope present only in extremely small amounts, the behavior of a "weighable" amount of the same substance. If, for example, the radioactivity is precipitated in an acid solution by hydrogen sulphide, together with copper, lead, and any other element that is precipitated by hydrogen sulphide, it is very probable that the radioactive substance will form an insoluble sulphide. Again

<sup>3</sup> To mention only one of the latest, the writer established correctly (*Phys. Rev.*, 55: 1104, 1939) several chemical properties of a certain substance, which properties he wrongly interpreted as showing that it was a rare earth until McMillan and Abelson (*Phys. Rev.*, 57: 1185, 1940) proved conclusively that it was an isotope of element 93.

if we can distill the radioactive substance under certain conditions we can also be reasonably sure that a large amount of it would be volatile under the same conditions. But other properties like the color, electric conductivity, specific gravity, etc., can not be measured with such minute amounts.

One thus sees that a study of the radiochemical properties of the remaining undiscovered elements 43, 61 and 85 might be expected to give interesting and valuable information.

Element 43 was prepared in the Berkeley cyclotron by bombarding molybdenum with deuterons or neutrons. It was identified and its radiochemical properties were investigated by Perrier and the writer in 1937. Its general behavior is very similar to that of its heavier homologue rhenium, but substantially different from that of its lighter homologue manganese. The separation from molybdenum, the parent element, is very easy and can be done in a few minutes. A detailed discussion of its chemical properties would exceed the limits of this article and for this we must refer to the original papers.<sup>4</sup> Although the quantities of element 43 so far prepared are too small for spectroscopic detection, it may be mentioned that the K lines of its x-ray spectrum have been observed although of course not in the usual way by exciting the spectrum on the anticathode of an x-ray tube. Their spontaneous emission occurring as a consequence of the transition from an upper to a lower excitation state of the nucleus gives detectable lines.<sup>5</sup> Element 43 can also be produced by alpha-particle bombardment of columbium and is separated from that element by sublimation in a stream of oxygen. By this method it can be deposited on an inert support as an invisible radioactive layer.

<sup>4</sup> C. Perrier and E. Segrè, *Jour. Chem. Phys.*, 5: 715, 1937; 7: 155, 1939.

<sup>5</sup> G. T. Seaborg, E. Segrè, *Phys. Rev.*, 55: 808, 1939. See also P. Abelson, *Phys. Rev.*, 56: 1, 1939.

In the case of element 61 the study of the chemical properties is somewhat superfluous because, since it is a rare earth, it is quite certain that its chemical properties will be extremely close to the properties of the other rare earths, and on the other hand no simple method of separation from them is to be expected. Several types of bombardments could give radioactive isotopes of element 61, but the interpretation of the results is not completely certain. There are good indications that praseodymium bombarded with alpha particles<sup>6</sup> gives an isotope of element 61. More work will be needed before a final conclusion can be reached.

Element 85 is a heavier homologue of iodine and has been prepared by the bombardment of bismuth with the high energy (32 Mev) alpha particles of the 60-inch Berkeley cyclotron.<sup>7</sup> Its chemical properties are notably different from the properties of iodine in so far as it shows marked metallic characteristics close to the properties of bismuth or polonium. For example, it is precipitated by hydrogen sulphide in acid solution, it is not precipitated like the halogenides by silver salts, and it is electroplated on several metals. It is also easily sublimed from the metallic bismuth and in this way it can be collected pure as an invisible radioactive layer.

The radioactive transformations involved in the decay of element 85 are also quite interesting, involving the capture of a K electron from the inner shell of electrons followed by the emission of an alpha-particle from the nucleus. The substance formed by the K capture of element 85 was already known in natural radioactivity as Ac C' and is a member of the actinium family.

The above-mentioned studies on elements 43 and 85 give a clear picture of

<sup>6</sup> J. D. Kurbatov, D. C. MacDonald, M. L. Pool, L. L. Quill, *Phys. Rev.*, 61: 106, 1942. C. S. Wu, E. Segrè, *Phys. Rev.*, 61: 203, 1942.

<sup>7</sup> D. Corson, R. MacKenzie, E. Segrè, *Phys. Rev.*, 58: 672, 1940.

most of the chemical analytical properties of these elements and can be used for a search for natural isotopes in two ways. First, they make possible predictions on the geochemical behavior of such elements and thus indicate the minerals most likely to contain them. Secondly, by using the artificial elements as tracers, they permit a continuous check on the enrichment processes.

From what is known of element 43, it seems very likely that it would be usually associated with rhenium. But the fact that many hundreds of pounds of rhenium have been isolated from various ores without any conclusive demonstration of the existence of element 43 seems to show that it does not exist in nature; this is as predicted by the systematics of nuclei.

The status of element 61 is similar to that of element 43, but although the great similarity of element 61 with the other rare earths makes the geochemical predictions very reliable, it is much more difficult to reach definite conclusions as to its existence from chemical evidence than for element 43.

The case of element 85 finally is considerably different because its properties differ substantially from these of its homologues. The failure of the searches performed in the past, for example, by Buch Andersen,<sup>8</sup> are inconclusive because we now know that the chemical operations performed would not have led to an enrichment of the substance looked for, but rather would have eliminated it. The Mattauch rules are also inapplicable in a region where all the elements are radioactive and it is not impossible that some isotope of element 85 may be found in nature.

To complete a discussion of the search for new elements, one should also include the transuranic elements. Their story, however, transcends the limits of this article, which deals with the completion, not the extension, of the periodic system.

<sup>8</sup> E. Buch Andersen, *K. Danske, Videnskab Selskab.*, 16: 5, 1938.

# QUININE: THE STORY OF CINCHONA

By NORMAN TAYLOR

DIRECTOR, CINCHONA PRODUCTS INSTITUTE, NEW YORK

If you happened to be a stranger in Missouri in the 1830's and stopped at Arrow Rock you might well think they were in the midst of a revival, for each evening the bells of the Methodist Church were rung rather vigorously. But it was not a call to prayer—merely a reminder for every one to take Dr. Sappington's pills. You would know why if you stayed through the sleepy, sluggish summer, for malaria stalked the land and the good doctor's pills were mostly quinine. He was one of the first and by far the most famous medico in the Mississippi Valley to use this remedy for malaria.

The disease was a curse to Arrow Rock, which nestled along the banks of the meandering and highly malarious Missouri River. And Dr. John Sappington, in his attempts to stamp out the disease, became, for a slightly different reason, almost as colorful as his direct descendant, Ginger Rogers. He is sometimes smirched as a quack, but several biographies, and notably his inclusion in the revered "Dictionary of American Biography" would seem to disprove it. Actually, more than any physician of his time, he knew that the treatment of malaria was not then what it should be and that the disease, unchecked, was blighting not only his own people but the waves of pioneers, so many of whom died along that swampy road to Eldorado.

The charge of quackery came as the result of a mistake. Sappington knew, as the "Autoerat of the Breakfast Table" wrote later, that "quinine . . . was among the sovereign and invaluable boons to humanity." Its use in malaria

had followed the isolation of the alkaloid in 1820, and the establishment of the first quinine factory in the world at Philadelphia in 1823.

To Philadelphia, then, Sappington sent his son to buy a certain number of ounces of the precious remedy, then worth about three dollars an ounce. The transaction completed, Dr. Sappington found that the youth had bought in *pounds* instead of ounces and the old gentleman was very nearly ruined. But he did possess a great stock of quinine. Convinced of its value in malaria, he invented "Dr. Sappington's Anti-fever Pills" and soon had pill peddlers all over the Mississippi Valley. In those days Methodist Church bells were just as good as the radio, and salesmanship, plus a little professional jealousy from Philadelphia, made him an anathema to the current purists on medical ethics.

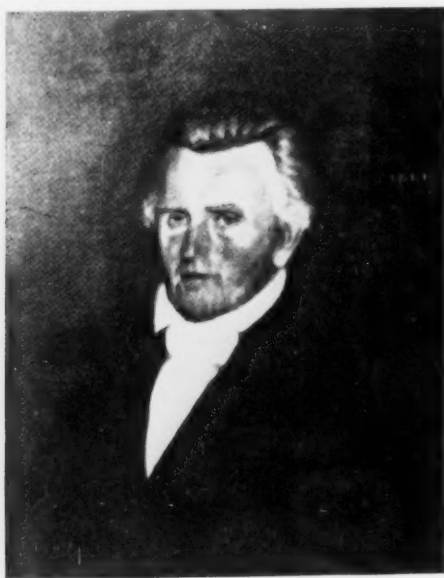
His true position has much to do with the story of quinine. Many years later, when the smoke of controversy had cleared away, Dr. Robert J. Terry, a medical historian, had this to say of Sappington:

The political enemies of Thomas Jefferson protested that in the Louisiana Purchase the United States acquired a swamp unfit for human habitation. The Mississippi Valley is to-day the home of millions. Who will say that the introduction and distribution of quinine in the early days was not a factor of great significance in establishing homes and settlements in a region infested with malaria? The control of malaria in the great valley required years of persistent effort under the hardships of frontier life and was not spectacular; was it less of a contribution to civilization than to-day's triumphs of sanitation for which we are justly proud?

Malaria is still the curse of all regions with warm summers and sluggish, mos-

quito-ridden water. Seventeen of our southern states still suffer from it and in the tropics it is far worse. The latest figures, which probably are too conservative, add up to the astounding world total of 800 million cases and over 3 million deaths annually. India has always been the worst sufferer.

To-day there hangs at Arrow Rock a portrait of Dr. Sappington by George Caleb Bingham, and rightly so, for he sensed the importance of malaria, and



DR. JOHN SAPPINGTON

OF ARROW ROCK, MISSOURI, A PIONEER IN THE USE OF QUININE IN THE MISSISSIPPI VALLEY. (FROM A PORTRAIT BY GEORGE CALEB BINGHAM, NOW IN THE OLD TAVERN IN ARROW ROCK.)

his work in that sleepy Missouri town presaged the world significance of quinine in the treatment and prophylaxis of that disease. He had many medical detractors, especially those who bled already depleted patients, almost to death. But he fought on and deserves at least a niche in the medical hall of fame.

What malaria is, and what quinine does to it, goes far back of the isolation

of the alkaloid by Pelletier and Caventou in a laboratory in Paris on September 11, 1820. For that discovery a statue of them was erected on the Boulevard St. Michel to commemorate an event that affects every one to-day—for upon quinine victory is largely dependent.

For quinine, pronounced *qui-neen'* everywhere except here, and universally called *kwy'-nine* in the United States, or *quin'-in* or even *qui-nine'* in Virginia, is one of the few real specifics known to medicine. The scholarly "Webster's" in defining the word "specific" says "exerting a peculiar influence over any part of the body; preventing or curing disease by a peculiar adaptation; as quinine is a *specific* medicine in malaria." (Italics theirs.)

But no one knows why. Hundreds of millions of malaria patients have been cured with it, and a huge amount of research has been accomplished on it, but we do not yet know how it works if, indeed, it ever works directly upon the microscopic plasmodium which is the cause of malaria. Perhaps no other drug has ever been so widely used with such complete ignorance of the mechanism of its action.

Its effects, however, are direct and unquestioned. They are perhaps best reflected in the world demand for it. Prescribed in grains, it is literally produced in tons. Just before the present war the world consumption was about 722 tons annually. Since the war, and before the invasion of Java, where most of the quinine trees grow, production for the year 1941 was 1017 tons. No tropical campaign can be run without it and our far-sighted government began to lay by a stock of it, long before Pearl Harbor.

Uncle Sam has been accused of bungling the rubber situation both before and since Pearl Harbor. But no one can accuse him of quinine bungling. The old gentleman has a longer memory than some of his detractors. He knew how



STATUE OF THE DISCOVERERS OF QUININE  
WHO ISOLATED THE ALKALOID IN A LABORATORY IN PARIS ON SEPTEMBER 11, 1820. THE STATUE WAS  
ERECTED ON THE BOULEVARD ST. MICHEL IN 1900 BY POPULAR SUBSCRIPTION.

General Gorgas made the Panama Canal possible, and why malaria would have stopped canal digging if Gorgas hadn't given nearly forty thousand doses of quinine per day—until he'd controlled mosquito breeding. Our government, or rather a handful of army and navy doctors, remembered that story and dreaded the malaria toll in possible tropical campaigns. So they began the accumulation of the largest stockpile of quinine ever gathered in this country. The amount is a military secret, and its whereabouts even more so.

It seems almost axiomatic that this competence of our army and navy doctors had to be matched by those who produced quinine. With ever so much foresight and a fat purse, Uncle Sam could still have been licked if there had been any futility about growing the tree that produces quinine or extracting the alkaloid from its bark. Why there was neither goes back to the slopes of the Andes well over three hundred years ago.

#### WHERE IT STARTED

From Colombia to Bolivia on the Amazonian slopes of the Andes there are many species of shrubs and trees of the genus *Cinchona*. All are first cousin to coffee and the ipecac, or in simpler terms, *Cinchona* belongs to the Rubiaceae. They are handsome plants with opposite leaves and pale pink or white flowers in lilac-like clusters. The bark of some of them is the only source of quinine. As in most tropical forests, they do not occur in pure stands, notwithstanding newspaper statements to the contrary.

Who first found that the bark of a few of these cinchona trees was good for ague, as malaria is often called, will probably never be known. Gracilasso de la Vega, a son of one of the conquerors of Peru, who married the daughter of an Inca noble, does not mention it in his "Royal Commentaries on the Incas." They had a word for it, *quina*, from

which is derived *quinine*, but there is no evidence that the Incas knew of the value of cinchona bark. About a century later the Jesuit priests at Lima do seem to have known of its value, hence its old name of Jesuit's bark, and later, Peruvian bark.

Somewhere about 1630 there was hatched the most colorful, romantic, and wholly untrue legend about cinchona, which this article, nor a dozen better ones, will scarcely eradicate. The story goes that the Countess of Chinchon, the wife of the Spanish viceroy, was stricken with malaria in Lima in 1630 and snatched from the verge of the grave by the timely intervention of adequate portions of the bark of quina. So grateful was the lady that the ground-up bark was promptly christened Countess' Powder and she is credited with introducing it to malaria-stricken Spain and Italy. It is a pretty legend, swallowed by Linnaeus, who named the trees *Cinchona*\* in her honor, and by everyone else until November, 1941.

The three-hundred year old canard was finally exploded by A. W. Haggis in the *Bulletin of the History of Medicine* for October and November, 1941, published at Johns Hopkins University. This proves that the countess never had malaria, that her husband often did, but that even for the viceroy there was no cure by cinchona bark, for no one at Lima then knew anything about it. Nor did the countess ever take it to Europe for she died on her way home, as is proved by the Archives of Franciscan Friars at Lima, who wrote:

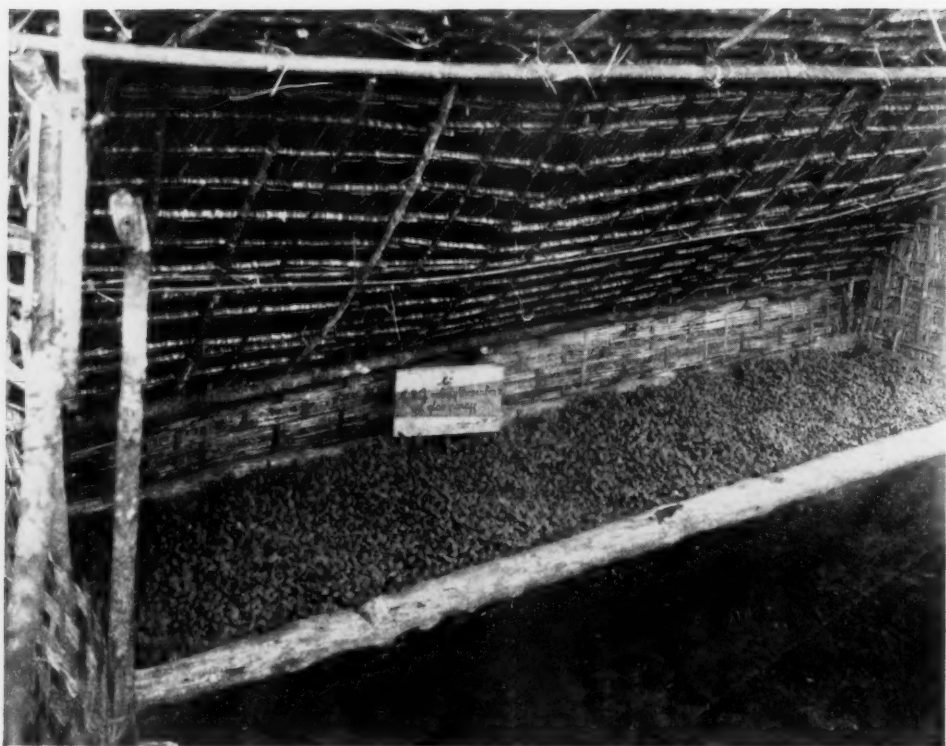
By these presents let it be known unto you how, on the 14th January of this year 1641, in the City of Cartagena of the Continent of this Kingdom, Our Lord gathered unto Himself, Donna Francisca Henriquez de Ribera, Countess of Chinchon, and a patroness of our Holy religion.

\* Linnaeus dropped an "h" in naming *Cinchona* for the Countess of Chinchon. According to the rules of botanical nomenclature his mistake must be perpetuated, notwithstanding the subsequent confusion in spelling.



PREANGER REGENCY IN WESTERN JAVA

WHERE CLIMATE, ELEVATION AND SOILS ARE MOST FAVORABLE FOR CINCHONA CULTURE.



Netherlands Information Bureau

#### A WELL-GERMINATED SEED BED OF CINCHONA SEEDLINGS

MANAGEMENT OF SEEDLINGS, TO PREVENT "DAMPING-OFF," IS NOT EASY IN WARM HUMID REGIONS.

This would seem to dispose of the Countess of Chinchon legend but tells us nothing as to who first took cinchona bark to Europe, nor when. It is first mentioned in European medical literature by a Belgian, Herman van der Heyden, in his "Discours et advis sur les flus de ventre douloureux," published at Antwerp in 1643. Its value must have been known then, and there the early history of *cinchona* must rest, awaiting further research.

Its history for the next two hundred years is marked by futility, extravagance, and towards the middle of last century, by a rapidly dwindling supply of the bark. For it should not be forgotten that for nearly two centuries infusions and extracts of the bark had been in world-wide use for malaria. Long be-

fore quinine was finally isolated as a powerful drug, patients were given bitter extracts of cinchona bark which, besides quinine, contains three other alkaloids—cinchonine, cinchonidine, and quinidine—which are also used in malaria.

So tremendous was the trade in bark that England and Holland became alarmed about the middle of the last century because each had highly malarious colonies and both feared that exhaustion of the dwindling bark supplies would spell disaster. Holland in the 1850's and England during our Civil War, sent out elaborately equipped expeditions to the Andes to secure seeds, plants, or any other material suitable for starting plantations in India and Java. Both expeditions failed because *Cinchona* contains

many worthless species and both the Dutch and the English secured the wrong kinds. The effects were disastrous for the English whose plantations in India have never paid, although quinine from them *must* be produced even at a loss, because of the huge population and the worst malaria incidence in the world.

There then entered the most fantastic episode in the long history of quinine. Completely unheralded, with no scientific training, no elaborate expedition, but a good deal of common sense, there lived at Puño, Peru, an Englishman by name Charles Ledger. While the British Expedition under Sir Clements Markham was scouring the Andes for *Cinchona*, Ledger went on about his alpaca trading and gathered cinchona bark as he had for

years. He rather fancied some barks from the headwaters of the Marmoré River, in nearby Bolivia, and ultimately secured, through a servant, fourteen pounds of seed from these trees. While Ledger knew that the bark from which they came was high in quinine, he little guessed that this collection was to change the whole future of the quinine industry.

He sent the lot to his brother in London with instructions to offer them for sale to the government for their plantations in India. The British declined. His brother then went to Holland and offered the shipment to the Netherlands government for their Java plantations. The prudent and thrifty Dutch bought one pound, for one hundred francs, with more to be paid if the seed produced trees



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#### BARK DRYING IN THE SUN

PRELIMINARY PREVENTION OF MILDEW IS ACCOMPLISHED BY DRYING THE BARK IN THESE FRAMES, AFTER WHICH IT IS OVEN-DRIED.

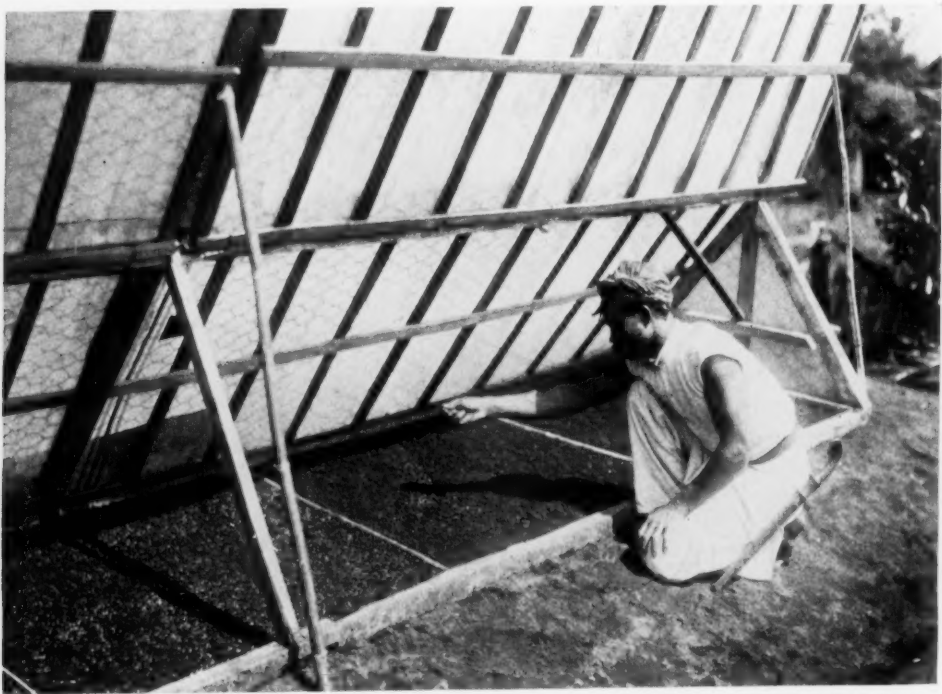
high in quinine. Soon after, they paid him a total of about a hundred dollars (£24) for the pound of seed.

The balance of the seed was sold by Ledger's brother to a British Indian planter, who went completely sour on his purchase and traded it for other varieties with the government cinchona plantations in India. The British Indian officials planted the Ledger seed but few ever germinated and these all died.

Meanwhile the single remaining pound of Ledger seed arrived in Java in December, 1865. It was planted at the Government Cinchona Plantation under the direction of K. W. van Gorkom, without any notion of what was to follow. Some of the seed had spoiled, but twenty thousand germinated and twelve thousand seedlings were set out the following year.

To four men, van Gorkom, J. C. B. Moens, J. E. de Vry, and M. Kerbosch, is due the final success of cinchona culture in Java. For forty years they persisted in their experiments in the face of bitter criticism from the people and at times from the government of the Netherlands Indies. The Government Cinchona Experimental Station at Tjinjiroean was ridiculed as "the expensive hobby." No private planters could be coaxed to grow cinchona. But to-day there are over a hundred private planters up in the mountains of Java, and until the island fell to the Japanese, the descendants of those magical trees from Ledger seed produced nearly all the quinine in the world. They were most appropriately christened, in proper Latin, *Cinchona ledgeriana*.

It is an oft told tale, and far too long to repeat here, of just how all this was



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CRITICAL STAGES OF CINCHONA CULTURE REQUIRE EXPERT CARE

accomplished. When it is remembered that *Cinchona* is as likely to spontaneously hybridize as blackberries, the ultimate standardization of a pure line with high quinine content seems all but miraculous. It is still more so because it antedated any knowledge of the Mendelian ratio which was rediscovered by another Dutchman, Hugo de Vries, at Amsterdam, in 1900.

In addition to controlled hybridization, of which the Dutch did a good deal, there was an extraordinary coordination of horticultural practice, soil science, chemistry, and forest succession. And this meant long-range planning, for the bark is gathered only by the destruction of the trees. The Dutch still carry on their experiments on cinchona culture, to maintain their excellent record, or to improve it. The present head of the Netherlands Indies Cinchona Experiment Station is Mr. M. A. van Roggen.

Any American horticulturist or forester of repute would be foolish to state that this extraordinary Dutch perfection of cinchona culture could not to-day be duplicated. So far it never has, however, in spite of the fact that the Netherlands Indies Government has freely given or sold seeds to those who have tried. Failures or equivocal results, both by foreign governments and private planters are recorded from India, Eritrea, St. Helena, Formosa, Indo-China, Belgian Congo, Reunion, the Caucasus, Madagascar, Hawaii, Tanganyika, Queensland, Burma, Uganda, Cameroons, Jamaica, and even in California. It has also been tried, somewhat more successfully, in the Philippines.

More recently the U. S. Department of Agriculture has germinated thousands of cinchona seedlings at Beltsville, Maryland, under glass. They are then shipped to climatically favorable places in tropi-



Netherlands Information Bureau  
NURSERY SEEDLINGS READY FOR THEIR FINAL PLANTING



Netherlands Information Bureau

#### WOMEN FIELD WORKERS WEAR BATIK SARONGS

THE MEN WEAR PRINTED COTTON JACKETS (KABAJAS) AS THEY WEED A JAVANESE PLANTATION OF YOUNG CINCHONA TREES.

cal America, with the hope that quinine production will ultimately come back to those Andean slopes from which it was taken. The enterprise at Beltsville is under the able management of Mr. B. Y. Morrison, who is chief of the Division of Plant Exploration and Introduction, of the Department of Agriculture. He has few illusions as to the long and difficult years ahead, although experimental plantings have been made in several countries, notably Puerto Rico, Costa Rica and Guatemala.

For the immediate future there seems only a slim chance of quantity production anywhere in the New World, because the main harvest of bark comes only after fifteen to twenty years, and there are many pitfalls. Perhaps American enterprise can do in ten years what it took the Dutch forty to accom-

plish, but even then the United States and the cooperating Latin American governments are starting almost from scratch. Guatemala, at the moment, holds the most promise, although it is climatically less favorable than the original home of *Cinchona*.

#### THE SITUATION TO-DAY

The commercial extraction of quinine is possible, in normal times, only where the bark contains 6 per cent. or more of quinine sulfate (which is *quinine*, to most of us). The success of the Java planters is based upon the fact that their trees never yield less than this, and often considerably more.

Most wild cinchona from South America is lucky if it contains as much as 2½-3 per cent. of quinine. All the huge commercial plantations in Ceylon were

automatically put out of business at the turn of the century for precisely this reason. Java bark came into full scale production about that time and both Ceylon and the wild bark trade in South America practically folded up.

Nearly all the world supply of quinine is, or was, until March, 1942, produced from Java bark. This was extracted partly by the largest quinine factory in existence at Bandoeng, Java, and the rest in a handful of European factories, or by the only two important quinine manufacturers in the United States.

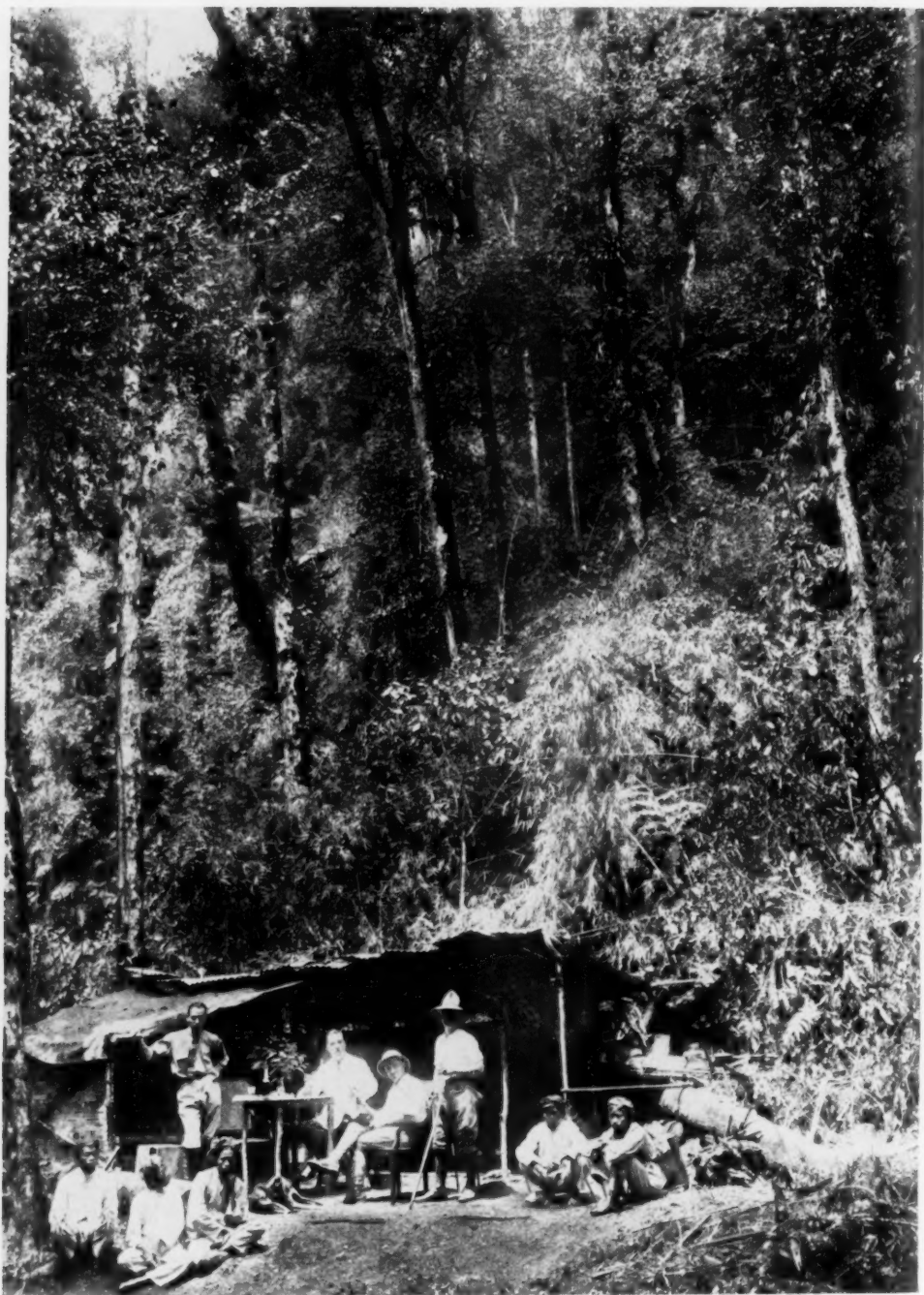
The combined production of these was ample for the world's needs, and even the vastly increased war demands for quinine were so well met that not only our government, as noted previously, but most large-scale pharmaceutical and proprietary establishments were able to build up stocks of quinine to anticipate the ultimate stoppage of shipments from Java.

Notwithstanding this foresight, something like panic seized the country when Java fell in March, 1942. Quinine, hitherto rarely mentioned in the news-



SOME TREES OF *CINCHONA LEDGERIANA*

AT THE NETHERLANDS INDIES GOVERNMENT CINCHONA ESTATE, TJINJIROEAN, JAVA.



*Netherlands Information Bureau*

A GROUP OF HIGHLY SKILLED PROSPECTORS

WHEN NEW CINCHONA PLANTATIONS ARE PROJECTED, MEN SUCH AS THESE CHOOSE THE SITES.

papers, yielded, through our clipping services, thousands of articles charging "shortage," "hoarding," "price-fixing," "government incompetence," "speculation," "monopoly," and a dozen other figments. Such was the public outcry that some congressmen, who should have known better, and a few self-appointed "experts" demanded that something should be done about quinine. Despite the fact that their ignorance of the real situation very nearly matched their clamor, Uncle Sam, of the long memory, became a bit perturbed. He finally silenced them by issuing three extremely wise orders.

The first was to limit quinine to its use in malaria. This worked an undeniable hardship upon those who had used it for years for colds and influenza. But we are at war, and no soldier should be denied quinine because of its diversion elsewhere. Malaria, in wartime, is more important than the common cold, even if 35 per cent. of all cold remedies do contain quinine.

The second was the manufacture of totaquina. This had never before been made in the United States, its use having been dictated by the low-yielding cinchona barks of India, Malaya, and the Philippines. The total alkaloids of these inferior barks were extracted and enough quinine added to bring the mixture up to therapeutic effectiveness. The name totaquina (*i.e.*, the total alkaloids of cinchona bark) and the formula for it were invented by the League of Nations Malaria Commission. It is a refinement of the old cinchona febrifuge, long used in India, and more effective than it. Today totaquina, which has been admitted to the new edition of the U. S. Pharmacopoeia, is made by at least three American manufacturers who rely upon the low-grade South and Central American barks, hitherto of little or no interest. These, with negligible exceptions, are worth next to nothing so far as the com-

mercial extraction of quinine is concerned, but they can be used to make totaquina which costs less than quinine, is considered a little less effective, and hence given in somewhat larger doses.

The third directive of our government controls all importations of cinchona bark from Tropical America, fixes a price for it based upon its alkaloidal content, and also fixes the price at which totaquina may be sold. Both orders



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LILAC-LIKE CLUSTERS  
OF FLOWERS OF *Cinchona ledgeriana*.

stopped ruinous bidding for cinchona bark and useless gouging of the public for totaquina.

In a democracy like ours it would be delirium of optimism to expect all this to have been accomplished without some faltering. There has been much of it, as between the several war-time agencies interested in quinine. But the plain fact is inescapable that Washington, in spite of all criticism, has safeguarded our



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## CINCHONA BARK GATHERERS

quinine supplies during the emergency and provided for the production of a reasonable war-time substitute for it in totaquina.

Totaquina, like quinine, must be used, for the duration, only for malaria. That is, and always has been, the chief use for quinine and the other alkaloids of cinchona. But some other uses are important. Besides the common cold and influenza, already mentioned, quinine has been used in minor surgery as an anesthetic, as a test for goiter, in Meniere's disease, for varicose veins, and in obstetrics for its reputed action on the muscles of the uterus. The *Quinine Formulary* also lists other uses for it, and the use of quinidine in auricular fibrillation. So important is the latter that the government permits its use for this purpose, because several thousand people would die of this heart affection without a daily maintenance dose of quinidine.

## OTHER REMEDIES

In a disease so world-wide as malaria it would be most surprising if many other remedies had not been put forward to challenge the undisputed position of first, cinchona, and then, quinine, during the past three hundred years. There have, in fact, been many. They range from the Civil War use of Georgia bark (*Pinckneya pubens*), the dogwood (*Cornus florida*), the bark of an ash tree in China, the emu apple of Australia, the "quinine" bark of California (*Garrya*), to the numerous old-wives' remedies, now long forgotten. Other, and more modern methods of chemotherapy also have their adherents. Among the latter are derivatives of the sulfa drugs, arsenic, epinephrine, and some others originally found in the laboratory of the I. G. Farbenindustrie in Germany. Of the latter, two have been admitted to the new edition of the "U. S. Pharmacopoeia" under the

names "quinaerine" and "pamaquine," which for some time had been known under their trade names of "atabrine" and "plasmochin."

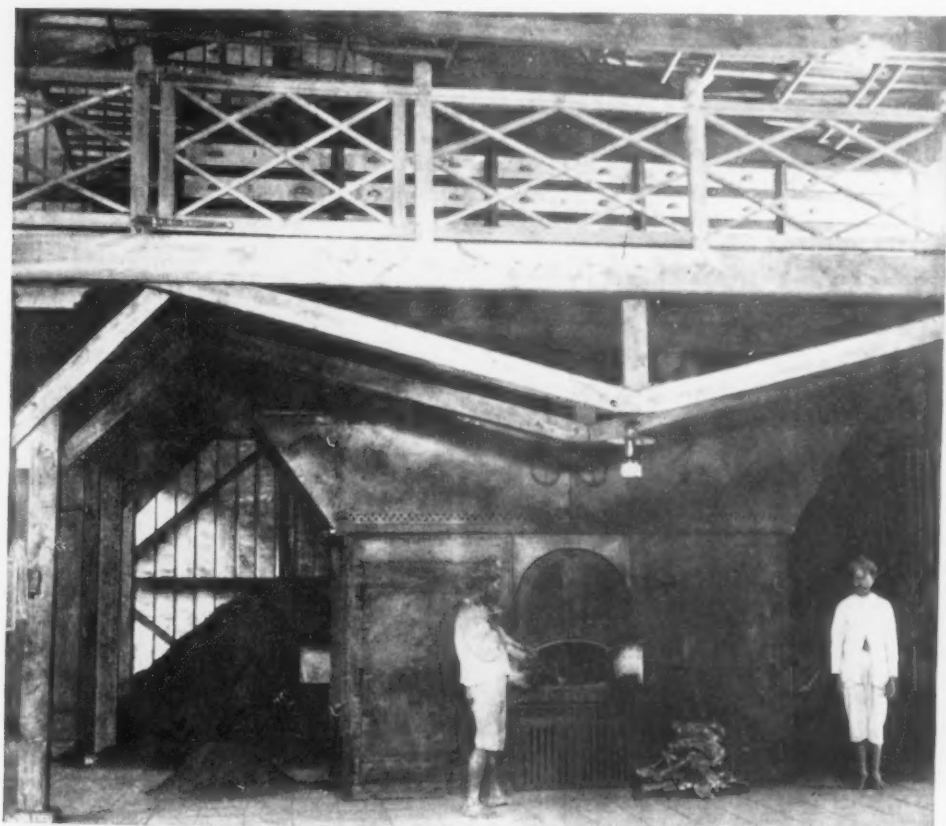
No one has ever yet found a real synthetic quinine, all the others being possible substitutes for it. Their position in the treatment of malaria to-day is perhaps best appraised in the report of the League of Nations Malaria Commission. In a book of 558 pages entitled "The Treatment of Malaria" (Geneva, December, 1937) they contrast the current malarial remedies, based on carefully controlled clinical tests on many thousands of patients from all over the world. Their summary:

Among those drugs *quinine* [italics theirs] still ranks first in current practise, by reason of its clinical effectiveness and almost complete absence of toxicity, coupled with the widespread knowledge of its use and dosage.

For many centuries malaria was supposed to come from the noxious evaporation of swamps, hence its name, malaria, (bad air). Nobel prize winner Sir Ronald Ross was the first to prove that mosquitoes were the only carriers of the plasmodium that causes it. But many simple people still follow Shakespeare, who wrote of malaria in *Julius Caesar*, warning Brutus not

To dare the vile contagion of the night,

That was written before cinchona bark



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CINCHONA BARK OVEN IN WHICH THE MOISTURE IS DRIVEN OFF

THE OVEN PICTURED ABOVE IS LOCATED IN BANDOENG, JAVA.



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## JAVANESE CINCHONA BARK GROUND AND BALED FOR SHIPMENT

reached Europe. Fifty years later the bark became the subject of incredible stories, of court intrigue, of ecclesiastical bickering, and a bitter battle among the medicos.

But it survived all this, and finally, through the isolation of quinine became one of medicine's few specifics. Why it did so suggests the not impossible notion that perhaps it was worth it.

EDITORIAL NOTE: The author has not undertaken to present the recent developments of the use of synthetic drugs in the treatment of malaria. Further information on the cause, treatment and prevention of malaria can be obtained from a volume recently published by the American Association for the Advancement of Science: "A Symposium on Human Malaria, with Special Reference to North America and the Caribbean Region," where, in an article by Dr. Hans Molitor, it is stated that "The introduction of synthetic compounds with anti-malarial properties, equal or superior to those of quinine, is one of the greatest triumphs of systematic chemotherapeutic research and the

first real advancement in the field of anti-malarial therapy since the introduction of quinine." The reader is also referred to Volume I of the 1943 edition of "Stitt's Diagnosis, Prevention and Treatment of Tropical Diseases" by Colonel Richard P. Strong, director of tropical medicine for the Medical Corps of the U. S. Army and emeritus professor of tropical medicine of the Harvard Medical School. Basing his statements upon the report of the Malaria Commission of the League of Nations (1937) Dr. Strong writes: "In ordinary cases of *P. vivax* infection, the Commission states it is almost immaterial whether quinine or atebirin be used for treatment. For mass treatment where little or no medical supervision is possible, the cinchona alkaloids are the most suitable. Medical supervision is necessary if atebirin be used. The administration of quinine preparations, and especially of synthetic drugs, by the parenteral route, should only be resorted to in special circumstances or cases.

"In regard to the conclusions of this Commission that the action of atebirin on relapses 'is slightly more effective than that of quinine, especially in the case of benign tertian and of certain strains of malignant tertian,' there is some difference of opinion."—W. C.

# CULTURAL INFLUENCES OF PENNSYLVANIA'S MOUNTAIN GAPS

## I. EARLY ADAPTATIONS OF NATURAL ROUTES

By Dr. BRADFORD WILLARD

PROFESSOR OF GEOLOGY, LEHIGH UNIVERSITY

WATER and wind gaps of the Appalachian Mountains, particularly in Pennsylvania, have played a significant role in the development of transportation, in the settlement of the "back country," and occasionally they have figured in military operations. The story of the peopling of our eastern seaboard by Europeans is elementary United States history. From scattered, feeble settlements, the population grew and pushed inland. Early adventurers and settlers of the Middle and Eastern Colonies discovered presently that they were separated from the western interior of the continent by a mountain wall that appeared all but impassable. But, as exploration added familiarity with the country, routes were found across the topographic barrier. Only the Hudson and Mohawk valleys in New York offered a complete, low-grade, though circuitous, passage to the west. Yet, other lines of migration were discovered farther to the south. It is to those in Pennsylvania that our attention will be chiefly turned, where routes lay along river valleys and through mountain gaps. In Pennsylvania certain local conditions also influenced their utilization more than in other states.

The geologist and the physiographer have studied the gaps and recorded the tale of how they originated and what their characteristics are. Pennsylvania is situated in a region of physiographic variety. Parts of it lie within the Appalachian Plateaus, Appalachian Valley, Appalachian Mountains, Piedmont and Coastal Plain Provinces. Crossing the

State from the east-central region in Lehigh and Northampton counties in a southwesterly direction to the south-central border in Franklin County is the Appalachian Valley Section of the Appalachian Valley Province. It is bounded on the southeast, partly by the Triassic Lowland Section of the Piedmont, partly by portions of the Appalachian Mountains Province. The rest of southeastern Pennsylvania to the Delaware and including the Triassic Lowland Section is grouped with the Piedmont Province except for a small area of Atlantic Coastal Plain Province bordering the Delaware River. Northwest of the Appalachian Valley Section comes the broad area of parallel or concentrically curving mountains and valleys known as the Ridge and Valley Section of the Appalachian Valley Province. Forming the western and northwestern border and rising as a steep escarpment facing this last division is the Allegheny Mountain Section of the Appalachian Plateaus Province. This region passes westward into the plateaus of the western part of the State. It is with the Ridge and Valley section that we are primarily concerned in the present discussion. Along its river valleys with their many water gaps, transportation routes have been opened. It is therefore in order to discuss briefly the origin of the mountain gaps. As to their utilization, it is the intention in this account to emphasize only those in Kittatinny Mountain, which is the first or southeasternmost range of the Valley and Ridge Section.

## ORIGIN OF THE GAPS

In order to understand the nature and origin of the gaps through the Appalachian Mountains of Pennsylvania, it is necessary to review the factors concerned with their making. There are two kinds of gaps included in this discussion, *water gaps*, those through which streams are now flowing, and *wind gaps*, which today are occupied by no streams of water.

The stratified rocks which today form our mountains and through which the water and wind gaps have been cut are old. Drop back in geologic time some 300,000,000 years or more to the Silurian period. From rocks of this age or younger, practically all of our prominent ridges and valleys have been sculptured. In those ancient years, geographic conditions in what we now call eastern North America were hardly suggestive of today's familiar features. East of the present mountains extend the piedmont and coastal plain and the submarine con-

tinental shelf. In Middle Paleozoic times there existed in this region and even beyond to the east a landmass. Perhaps continental in size, it is the *Appalachia* of the geologists and paleogeographers. Along its western edge, which corresponded roughly to the present eastern border of the Appalachian Mountains, ran a sea coast. Although a western coast, it opened upon anything but the Pacific Ocean as known today. It was the eastern shore of an inland sea which lapped over part of the interior of the continent. In its shallow water, limy muds accumulated far from shore. Simultaneously, along that Paleozoic coast of Appalachia, sands and muds and pebble beds were laid down where beaches fringed the land. Waves eroded as they pounded the coast; tides and currents contributed their part in spreading sediments. Rivers and streams flowing off the land brought seaward their loads to be dropped as deltas or swept away into deeper water. Most of the



FIG. 1. DELAWARE WATER GAP FROM THE SOUTH

AMERICAN WATER GAPS HAVE LONG BEEN USED BY RAILROADS AND OTHER MEANS OF TRANSPORTATION IN PASSING THROUGH THE MOUNTAINS. THE ROUTES WHICH HAVE DEVELOPED IN THIS WAY ARE NOW MARKED BY INDUSTRIAL CENTERS.



FIG. 2. VIEW OF WIND GAP FROM THE SOUTH IN NORTHAMPTON COUNTY. THE WIND GAPS, TOO HIGH FOR CANAL OCCUPATION, HAVE SOMETIMES BEEN USED BY RAILROADS. MODERN HIGHWAYS MAKE EXTENSIVE USE OF THEM. THROUGH THIS PARTICULAR GAP MARCHED GENERAL SULLIVAN'S ARMY ALONG THE ROUTE NOW OCCUPIED BY STATE HIGHWAY NO. 12.

sediments fell to the bottom near shore. Many show signs of deposition in shallow water. Yet they are in their total many thousands of feet thick.

Despite the amount of mud, sand, gravel and precipitates which the sea acquired, it failed to fill up for a very long time. For some millions of years, even as layer upon layer of sediments spread over the bottom, that bottom, instead of

building up to sea level and changing to land, subsided beneath its load. The load, greatest near shore, lessened westward in proportion to thinning of beds away from the coast. In time, a long, narrow lens or wedge of sediments evolved over the subsiding ocean bottom along the western coast of Appalachia. Because the bottom continued to sink, roughly in proportion to the amount of

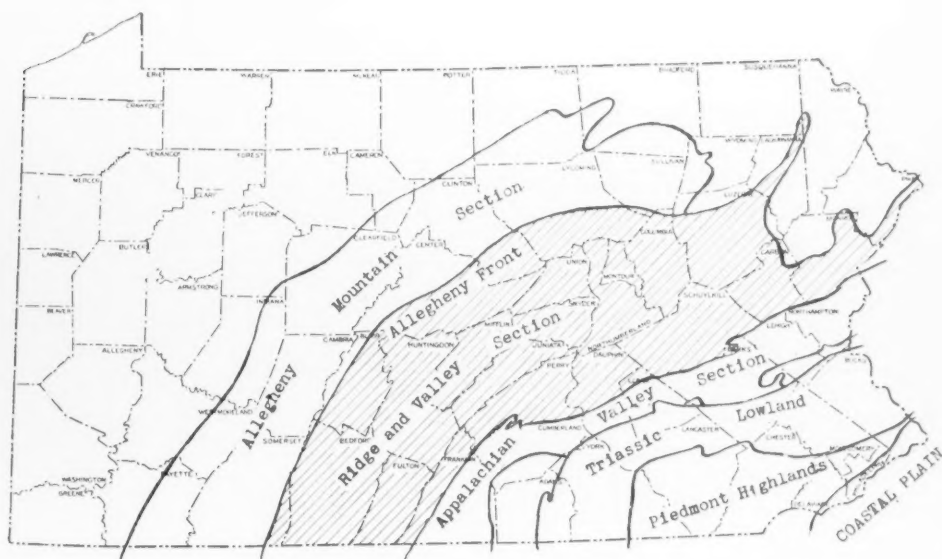


FIG. 3. PHYSIOGRAPHIC SUBDIVISIONS IN PENNSYLVANIA. THE RIDGE AND VALLEY SECTION IS SHADED. (PARTLY AFTER ASHLEY.)

sediment added, thousands of feet of strata accumulated. They were piled up in the sea, but sea level remained constant over the subsiding region. Such a region, sinking under the weight of sediments, is geologically dubbed a *geosyncline* or syncline of deposition. The process which adjusts the earth's crust to keep pace with the growing load of layers, is complicated. Its sponsors are the geophysicists who refer to it as *isostatic adjustment*.

Here in the Appalachian geosyncline, originated the rocks of our present-day landscape. The old seaway engendered our mountains! Examine rock cuts along mountain-penetrating highways. There are layers of gravel, sand, mud, limy beds turned to solid rock. Some beds are filled with fossil sea shells. Others perhaps are marked by tracks of ancient, crawling creatures. More may enclose

shreds and mats of an antique vegetable world. Besides these fossils, there are also such false fossils as ripple marks formed where shallow water currents stirred the mud and sand of rocks-to-be. Cracks show where the mud dried and shrank at low tide,—and perhaps one finds the little dimples produced by rain drops as a short, quick shower passed over mud exposed to the Silurian or Devonian clouds. Is clearer evidence needed to confirm the origin of these rocks?

Once flat layers on the sea bottom, these beds no longer lie flat. Many are folded and distorted far from their original positions. Others are broken and crushed over their neighbors. Some time after these strata were deposited and had consolidated to hard rock, something happened to crumple them. Eventually, or perhaps during folding, the whole area was lifted bodily up, out of the sea. Not merely did it become dry land; actually it rose to mountain heights from the area where once the waters of the inland sea had rippled.

The *modus operandi* of mountain building is obscure. The results are evident. The changes since the time of the geosyncline to the present may have been something as follows.

The process called isostatic adjustment slowed down and finally ceased altogether. As adjustment stopped, the sea bottom no longer dropped out as deposition loaded it. The sea filled up, a change evidenced in the rock succession. Whereas the earlier beds of the geosynclinal prism were formed in the sea, and carry traces of marine life, the latest ones formed in fresh water or on land and contain land plants, whose residuum today is coal. Even as the geosyncline was filled, Appalachia was so worn down that the supply of sediments from that source ended. The filling of the geosyncline to form dry land and the final degradation of Appalachia were synchronous events. One of those

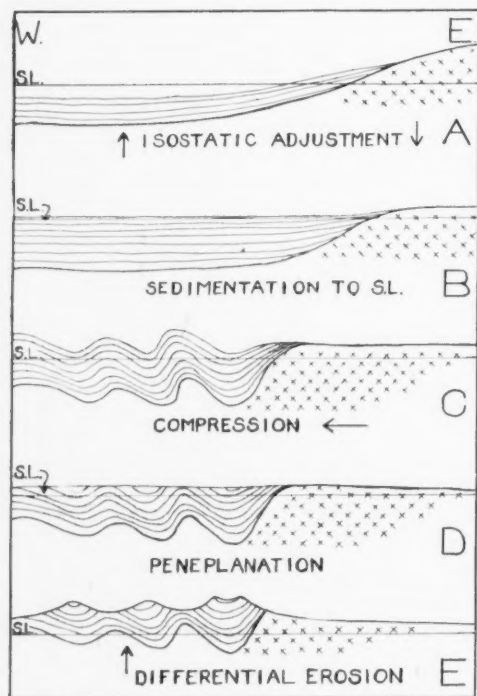


FIG. 4. CROSS SECTION DIAGRAMS SHOWING THE SUCCESSIVE STEPS FROM GEOSYNCLINAL DEPOSITION TO DEVELOPMENT OF THE PRESENT APPALACHIAN MOUNTAINS.

major earth paroxysms called a geologic revolution followed.

During such a revolutionary interval, compressive forces fold and break the rocks of the earth's crust. In the *Appalachian Revolution* which affected the eastern part of the United States, the ancient land mass, Appalachia, was pushed bodily westward or northwestward. Squeezed vise-like were the geosynclinal sediments in its path. As snow is shoved before the advancing shovel edge or plow, so did the rocks pile up. Simultaneously, or immediately following the interval of compression, the region of the geosyncline was uplifted, that of Appalachia subsided. The relative altitudes of the two areas reversed themselves. The erstwhile sea-floored geosyncline became a region of folded rocks raised as the ancestral Appalachian Mountains. The old land to the east went down, perhaps not at once, wholly below sea level, but low enough so that now fresh-water, later on marine, sediments began to accumulate on its surface.

Examine a little more carefully these rocks rescued from the bed of the ancient sea and raised in folded mountain chains. They vary among themselves both in relative thickness of the individual strata and in the physical and chemical features of the beds, that is, their lithology. Some layers or whole formations are soluble limestone, others soft shale. In contrast are those of hard and insoluble sandstone and beds of pebbly conglomerate.

Such unequally resistant beds, folded, raised and exposed to the elements, weather and erode at different rates. Every crack along the folds is an incipient focus of destruction at which chemical and physical forces may attack. The hard or resistant outlast the soft or soluble. Slowly, by processes of rotting away, wearing away and carrying away, the long, parallel folds of rock were etched out to yield long, parallel ridges and valleys. Yet these are not today's

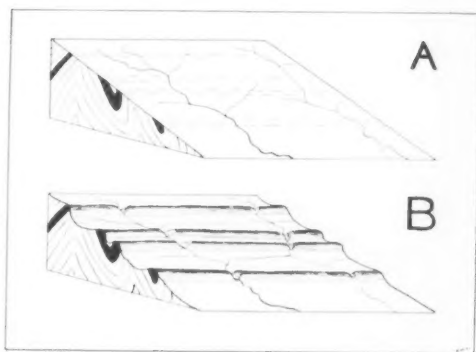


FIG. 5. WATER AND WIND GAPS  
DIAGRAMS SHOWING THE DEVELOPMENT OF THE GAPS. (A) NEWLY UPLIFTED (TILTED), PENEPLANED SURFACE UNDERLAIN BY FOLDED ROCKS OF VARYING HARDNESSES; CONSEQUENT STREAM PATTERN DEVELOPED. (B) SUBSEQUENT STREAM PATTERN DEVELOPED. THE MASTER STREAM, LEFT, HAS MAINTAINED ITS COURSE ACROSS DEVELOPING RIDGES; A SECONDARY STREAM, RIGHT, HAS BEEN CAPTURED, LEAVING A WIND GAP. TRIBUTARIES ARE ADJUSTED TO NON-RESISTANT, VALLEY FORMING BEDS. THE HARD, RIDGE-MAKING ELEMENT IS IN BLACK ON THE LEFT OF THE DIAGRAMS.

relief features; another cycle of uplift and degradation came on. Given sufficient time, a factor with which geologists are always generous, even the hardest beds would conceivably be reduced essentially to sea level. The folded, raised, eroded region of geosyncline-formed sediments was brought low to a nearly featureless surface. Over it, eastward wandering rivers wound complacently to the not-so-distant Atlantic Ocean. Note well that these streams ran eastward, not westward as in the ancient days of the geosyncline and Appalachia. Already modernization was foreshadowed.

Once again uplift affected the degraded or peneplaned folds. Once more the region was pushed bodily up even as high as the loftiest crests of the present Appalachians. But the rate of elevation was so gradual that the principal streams "kept the noiseless tenor of their way." Holding to their original, winding courses inherited from old peneplain days, rivers ancestral to the Delaware,

Lehigh, Susquehanna, Schuylkill and Potomac, some lesser, local streams, too, continued to flow along essentially the lines already established. Beneath the raised but nearly flat surface of the peneplain, grovelled folded rock-roots of humbled mountains. The hidden rocks resembled wood grain, parallel or converging bands. Like the well-worn, foot-wide floor boards of some colonial farm house, long erosion might bring into relief hidden inequalities. Because some rivers were large, powerful, they cut cross-grain impartially through hard and soft rock bands alike (Fig. 5). The lesser side-streams, the small tributaries, incapable of maintaining their courses, adopted paths of least resistance and presently adjusted themselves to flow along the bands of soft or soluble, non-resistant rock. Where the master streams crossed such bands along their valleys, the tributaries made confluence with them. Again, the whole, rising surface was etched out into a series of parallel ridges and valleys, carved from the established rocky grain of the country. Through the ridges the mightier rivers

cut deep gashes, the water gaps. Down the side valleys the lesser water courses meandered to join the master streams.

On some clear day stand atop one of our ridges. How long and straight it looks! Sight away off across adjacent mountain tops. Note the gaps; but see also how ruler-straight is many-a ridge top. Can it be that each ridge crest is a trace or remnant, a part of the ancient peneplain? Such is the explanation. Each ridge is composed of harder rock which remained upstanding as a remnant while soft beds were gouged out in valleys, deeply eroded below the peneplain surface.

The story behind the gaps is not quite done. We have still to tell how the wind gaps fit into the scheme of landscape etching. During the process of gap cutting and valley erosion when the old peneplain was rising, there were certain streams, now extinct, whose courses lay across the grain. For one reason or another they failed to maintain those courses, were eventually diverted to easier, grain-parallel routes. But, during the time when they were engaged in



FIG. 6. IN THE RIDGE AND VALLEY SECTION OF FULTON COUNTY  
NOTE THE LONG, EVEN-CRESTED RIDGES UNDERLAIN BY UP-TILTED, HARD BEDS. THE INTERVENING VALLEYS ARE CUT IN SOFTER ROCK. ONE OF THE RIDGES IN THE MIDDLE DISTANCE IN THE PICTURE IS BREACHED BY A GAP.

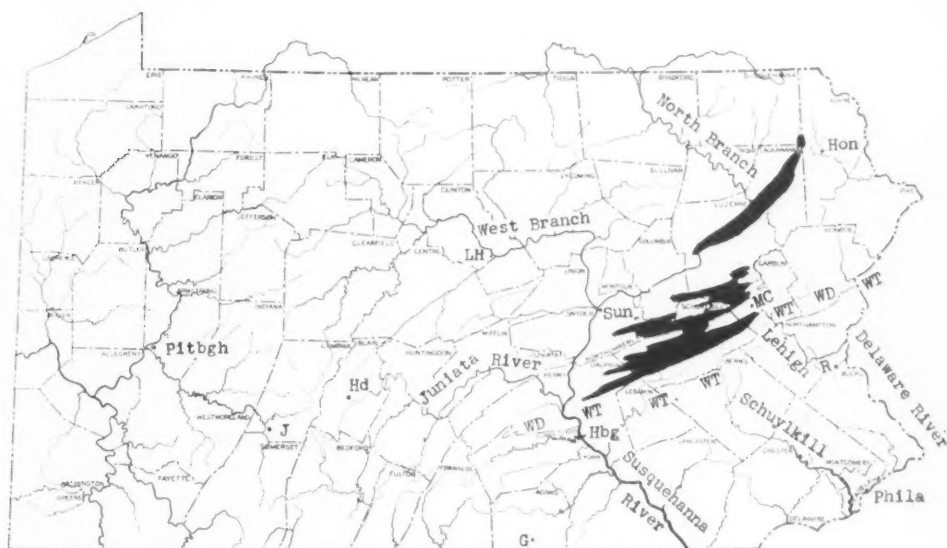


FIG. 7. SKETCH MAP OF PENNSYLVANIA

SHOWING PRINCIPAL RIVERS, WATER AND WIND GAPS AND IMPORTANT TOWNS MENTIONED IN THE TEXT. ANTHRACITE FIELDS ARE IN BLACK. KEY: WD, WIND GAP; WT, WATER GAP; G, GETTYSBURG; HBG, HARRISBURG; HD, HOLLIDAYSBURG; HON, HONESDALE; J, JOHNSTOWN; LH, LOCK HAVEN; MC, MAUCH CHUNK; PITBGH, PITTSBURGH; PHILA, PHILADELPHIA; SUN, SUNBURY.

transecting the resistant bands, appreciable gaps were made. With stream diversion, such notches were left dry, literally thrown to the winds. So, each wind gap today marks the deserted channel of a defunct river. What has been the influence of these wind gaps and water gaps upon man and his works and movements?

#### MAN USES THE GAPS

##### *Early Strategic Importance*

In Colonial days, few white men from the east penetrated the Appalachian Mountains in the region of Pennsylvania and southward. The broad path of the Hudson and Mohawk valleys to the north was early known and used. About the year 1732 men moving out along the Potomac in Virginia entered the Shenandoah Valley. Twenty years later the first drops of the great stream of migrants began to pass from Pennsylvania and Maryland into the headwaters of the Ohio. To the south Daniel Boone's

journeys blazed sunset trails for the people of North Carolina and Virginia. While Boone's Wilderness Road led into Kentucky and Tennessee, others penetrated Pennsylvania from Philadelphia to the region of present-day Pittsburgh and from Baltimore out along the Potomac Valley. Of these, Boone's was probably most used in pre-Revolutionary days. It is said that several thousands of people passed over it yearly. All of these advances followed through or were influenced by natural topographic routes; that is, river valleys and mountain gaps. Such natural routes have ever since dominated travel from the Atlantic seaboard west through the Appalachian barrier.

In contrast to the relation to transmontane journeys of Colonial times, the mountains served as a welcome rampart and protection against the revengeful savages bent on exterminating the white usurpers of their ancestral homes along the coast. The mountain gaps, con-

versely, were at times a genuine menace rather than an asset. For ages the red men had traveled them. Through them threaded the war and hunting parties. They were routes of savage migration and primitive trade. With the establishment of the whites on the lowlands to the east, the gaps became ideal Indian ports of sortie upon the unwelcome settlers.

This was particularly emphasized during the conflict with the French and Indians. Facing each important gap, a blockhouse presented its sturdy walls against surprises. Many of these strategically distributed forts from the Delaware to the Susquehanna were erected through the foresight of Benjamin Franklin. Typical of defenses were those at the Lehigh Water Gap, which figured conspicuously in frontier forays and bloody Indian fights. A blockhouse is reported to have existed as early as 1739 near the present town of Northampton in Northampton County. Later forts guarded both sides of the river below the Gap. Such forts were usually

small, octagonal structures with loop holes and a door but no windows through their two feet thick walls. Today there remain few of these forts. Sites of vanished others are appropriately commemorated by markers and monuments. Names, too, reminiscent of our early wars, cling as in Fort Hunter, Forty Fort and Fort Loudon.

White men made military use of the gaps during the last of our colonial wars. When Braddock's ill-adapted troops trudged arduous miles westward across southwestern Pennsylvania against Fort Duquesne, every advantage was taken of such gaps as there are in our more southern mountains. Wagon trains meant wagon roads. Braddock's Road became in time one of our principal routes of travel to the west, and parts are incorporated today into our modern highways. Because Braddock's road was built partly under the direction of George Washington, we may truly number the First President among those responsible for the beginnings of our



FIG. 8. OLD INDIAN FORT

LOCATED IN BERKS COUNTY. THE FORT IS THE SMALL STONE BUILDING WITH A CONICAL ROOF.

present highway system. Bedford County had its first permanent white settlement in 1750 at "Raystown." Five years later, 1755, a wagon road was opened from Fort Loudon west to join Braddock's Road in Somerset County. Further development came when Forbes' army erected a fort at Bedford, 1758. Forbes followed a trail called Nema-colin's after the Indian guide. Begun at Cumberland, Forbes' Road pursued a somewhat north of west course to the Youghiogheny, utilizing a number of small gaps. The road intersected the River at the "Great Crossing" south of the present town of Somerfield.

Military uses of the gaps again figured in the Revolutionary War. As before, the mountains formed a barrier, but the gaps had to be defended. The Wyoming massacre effected by a British raid down the Susquehanna, was a realization of an attack such as was constantly feared. Before the close of the war, the Colonial troops of General Sullivan's punitive expedition into western New York were on the march. This is an instance of military use of the gaps. Setting out from Easton, Pennsylvania, in the early summer of 1779, Sullivan's army traversed the Wind Gap (Fig. 2), went past Tannersville, at that time an outpost of civilization, over the Pocono Plateau to Fort Wyoming (now Wilkes-Barre) and thence up the Susquehanna Valley into New York. In collaboration with Sullivan, Colonel Daniel Brodhead led another party up the West Branch of the Susquehanna into northwestern Pennsylvania. Fort Augusta (Sunbury today) at the forks of the Susquehanna was a base of supplies. So, in these troop movements during the War for Independence, the river routes and the gaps proved the best lines of march.

#### *Roads and River Boats*

The Revolution was followed by the steady increase in westward movement

of a people which until then had remained essentially confined to the seaboard. The nation was determined to expand across the mountains into the fabulous Ohio Valley lands. With the removal of Indian menaces, river-following trails became roads which through improvement gradually grew into the main communication arteries of the early Republic. Typical of these was the National Road or Cumberland Turnpike which was built during the years 1808 to 1817. It connected the Potomac with the Ohio. Slowly, but with acceleration, crooked Indian trails evolved into tote-roads, pack-roads and wagon-roads in turn. "Practically the whole present-day system of travel and transportation in America east of the Mississippi River, including many turnpikes, is based upon, or follows, the system of forest paths established by Indians hundreds of years ago."<sup>1</sup> Gradually, horses and "shanks mares" were displaced by carriages and coaches. First introduced as public vehicles in the Colonies about 1730, it was not until long afterward that the coach was used in trans-montane journeys. The need of better roads developed soon with the increase of travel across the Alleghenies. The first fundamental improvement appears to have been in response to the use of wheeled vehicles, when a reasonably firm surface became imperative. Even after coach roads were well established in the east, it was impossible to go west by this means. A journey from Philadelphia to Pittsburgh soon after the Revolution permitted the use of the coach only to Shippensburg, 140 miles; the remaining 170 had to be made a-foot or a-horseback. For freight transport, the pack train presently was superseded by the Conestoga wagon, ancestor of the prairie schooner. These famous vehicles are gone save as museum pieces; but the name is immortalized, if not too honorably, in those all-powerful cigars,

<sup>1</sup> Dunbar, Seymour, "A History of Travel in America," 1937, p. 19.

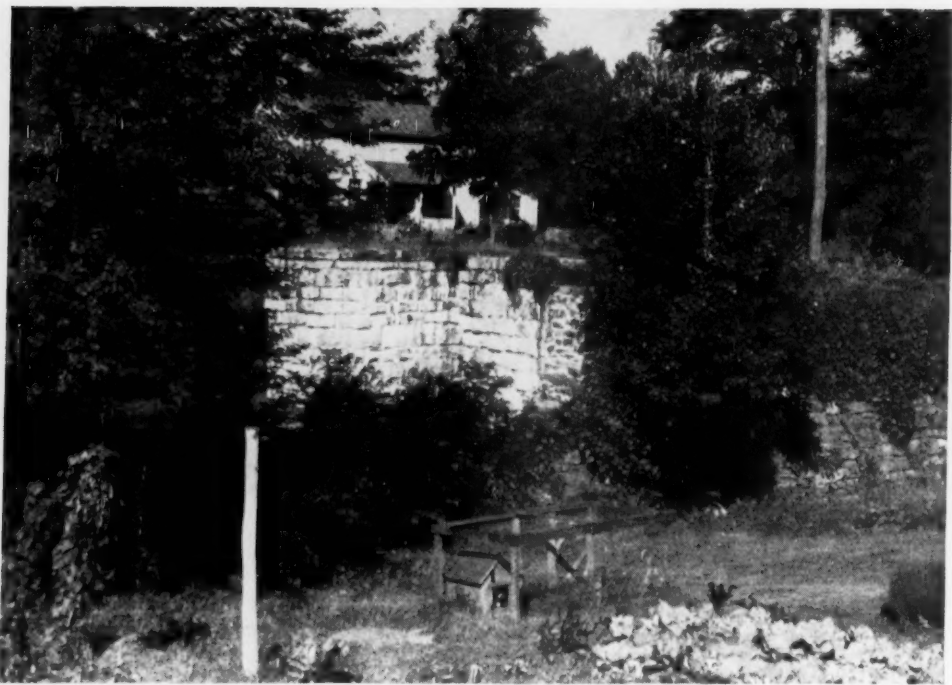


FIG. 9. CRUMBLING MASONRY—REMAINS OF ONCE BUSY CANAL LOCKS  
THE LOCKS PICTURED ABOVE ARE ON THE SCHUYLKILL CANAL ABOVE HAMBURG, BERKS COUNTY.

the "stogies" or "conestogies". Reputedly, none but the cast iron constitution of the driver of a Conestoga ("Stogie") wagon could survive this species of fumigation. Roads continued to press westward, even beyond the mountains. The Cumberland Road was eventually extended into the Mississippi Valley as the main east-west route from the Original Thirteen to the newly admitted Middle Western States. Over it streamed coaches, freight wagons, pack trains in interminable parade. Its construction was partly dependent upon the use of water gaps in overcoming the mountains that lay across its path.

But even as the Pennsylvania-made "Kentucky" rifle cleared the forests of Indians and the Pennsylvania-invented Conestoga wagon hauled the settlers' goods along the new roads, accounts of another means of transportation were on men's tongues. This means was water

travel. The canal did not come into immediate use. Its development as a low-grade route was antedated by earlier and cruder trials of methods of water transportation. In the beginning use was made directly of unimproved, natural waterways.

The Indians had devised two types of boats, the bark canoe and the dugout or pirogue. Civilization brought larger and more serviceable craft. Several types were developed for river navigation, among them the ark, barge and keel boat. The name pole boat was in common use designating almost any type which was worked laborously upstream by means of poles pushed against the bottom by the crew. The ark, on the other hand, was a massive, heavy-timbered affair intended merely for floating down stream largely as the current willed. Arrived at its destination, it was commonly broken up and sold for timbers. The

barge was built lighter, more along the lines of a canoe. It could be pushed up stream. Some barges were fitted with a mast and sail and provided with a shelter for crew or passengers. Of peculiarly Pennsylvanian origin was the Durham boat capable of carrying some 15 to 20 tons of freight. It differed from the keel boat in that it lacked the distinctive keel of the latter, though provided with mast and sail. Timber rafts were also plentiful. Hundreds of them annually came down the Susquehanna to Harrisburg with high water.

Originally most of the boats carried lumber, farm produce, furs and passengers. With the growing exploitation of anthracite, various types of craft were used as coal-bearers. By them, anthracite could be shipped to Philadelphia and other seaboard destinations. Steam navigation of the shallow rivers of Pennsylvania proved a failure. A line of small, shallow draft steamers is said to have operated on the Susquehanna and Juniata as far as Millerstown, but it was soon abandoned. Ice in winter and low water in summer proved two costly interruptions or hindrances to navigation.

So, through adoption and adaption of several boat types, the rivers were put to use. Once more the gaps saw a new type of transportation taking advantage of such convenient passages of the mountains. In the river craft, the coming of the canal was hinted. River boats at

best were a makeshift. Indeed, it was in the very fact that they were makeshifts that the idea of canal building found its support if not its inception. For years, the people had believed that the rivers afforded sufficient channels for all commercial navigation. However, it was realized that certain obstacles, principally rapids or falls, along the streams, were serious problems to the river boats, especially in times of low water. Therefore, it was presently proposed that means of bypassing these barriers be devised and installed. Even before the Revolution, in the early 1760's, public agitation called for and suggestions were made to improve water transportation along the Susquehanna River and the Schuylkill. Benjamin Franklin early recommended betterment of the waterways, if not the actual construction of canals. In 1772 he is reported to have advocated improved navigation conditions along the Schuylkill with a view to opening the back country. At that time, be it reiterated, coal was not an article of river traffic. George Washington, too, seems to have been impressed, doubtless in part because of his experience in surveying. He was influential in promulgating as far back as 1784, the plan for the Chesapeake and Ohio canal. With a view to opening navigable water communication through to the West, surveys were made and reports submitted.

*(To be concluded)*

# HOPI SNAKE HANDLING

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EVER since 1884, when the Snake Dance of the Hopi Indians was first described in detail, attention has centered on that portion of the ritual during which some of the performers carry live snakes, including dangerous rattlers, dangling from their lips.<sup>1</sup> Again and again observers have wondered why it is that venomous reptiles are so freely handled, yet rarely is a Snake dancer bitten, and never has a fatality been reported among participants in the ceremony. Many theories have been proposed to account for this phenomenon, some writers attributing the scarcity of accidents to the remarkable skill of the snake handlers; others quoting members of the Snake Society who have claimed that they are immune to harm if their characters are good; and one author referring vaguely to a medicine which may stupefy the reptiles while they are being carried in the mouths of the performers.

On the whole there seems to be little need for postulating the use of drugs or the possession of any extraordinary or mysterious quality to account for the relative infrequency of injuries to the Snake dancers. Such unwarranted "explanations" have been completely dismissed by L. M. Klauber, curator of reptiles at the Zoological Society of San Diego, who has expressed the belief that accidents are rare partly because most rattlesnakes bite far less frequently than

<sup>1</sup> In reality, the so-called Snake Dance is only a brief public spectacle which comes as the culmination of a nine-day esoteric ceremony. One of the fullest and most accurate descriptions of the entire ritual may be found in G. A. Dorsey and H. R. Voth, "The Mishongnovi Ceremonies of the Snake and Antelope Fraternities," Chicago: Field Columbian Museum, 1903.

is commonly thought, and partly because all reptiles tend to become lethargic and docile after they have been handled in captivity for a number of days.<sup>2</sup> It may well be that Hopi dancers are fairly clever snake handlers, but in Klauber's opinion they are bitten just about as often as would be the case among a comparable number of white men who had been trained to deal with snakes.

If it be granted that native performers are actually stricken by venomous reptiles from time to time, as our records reveal, how does it happen that they seldom show ill effects and apparently never suffer death?<sup>3</sup> To this question the conventional answer has been that the Indians possess a secret medicine which serves as a potent immunizer or antidote. However, when tested in the laboratory the Hopi remedy has failed to show any efficacy. This was established by Dr. George E. Coleman, who once managed to secure about a pint of the reputed Hopi antidote with which he conducted experiments on a number of guinea pigs. Unfortunately, the liquid was no longer fresh at the time that the tests were made, but under the prevailing conditions, Dr. Coleman concluded that "the antidote certainly does not neutralize the venom in vitro."<sup>4</sup>

Since there is no indication that the Hopi medicine possesses any therapeutic

<sup>2</sup> L. M. Klauber, "A Herpetological Review of the Hopi Snake Dance," *Bulletin* No. 9, Zoological Society of San Diego, 1932, p. 32.

<sup>3</sup> For example, J. W. Fewkes, *Journal of American Folk-Lore*, 8: 280, 1908, tells of a dancer who was bitten, presumably by a rattler. Yet, his "wound was not fatal, nor did his hand swell up, as ordinarily happens a few hours after such a mishap."

<sup>4</sup> G. E. Coleman, *Bulletin of the Antivenin Institute of America*, 1: 99, 1928.

value, we must seek some other explanation for the lack of serious consequences when snake men are bitten by venomous reptiles. This brings us to the crux of our problem—are the poisonous snakes defanged, or “milked” of their venom, at some time prior to the public portions of the ceremony? These points have been widely debated, and a review of the literature pertaining to the Snake Dance clearly reveals that the great majority of authors favor the proposition that the reptiles are not rendered innocuous by either of these methods. This attitude was first expressed in 1884 when Bourke wrote, “Let it not be imagined that these snakes were harmless, that their fangs had been extracted, . . . we were all convinced that they had been subject to no treatment whatever.”<sup>6</sup> Nearly twenty years later, Dr. Dorsey took a similar stand. “This much may be said with confidence,” he wrote, “there is

<sup>6</sup>J. G. Bourke, “The Snake-Dance of the Moquis of Arizona,” p. 140. New York: Charles Scribner’s Sons, 1884.

absolutely no attempt on the part of the Hopi to extricate the fangs or in any other way whatsoever to render the snakes harmless.”<sup>7</sup> Still another writer, one never given to understatement where the American Indians are concerned, waxes almost hysterical at the accusation that the Snake Dance is a fake because the reptiles have been made safe. “Any one who knows anything about rattlesnakes,” he maintains, “knows that they can not be rendered harmless except by killing them. For the snake dance, their fangs are not extracted . . . the snakes are certainly not rendered innocuous.”<sup>7</sup>

Such has been the prevailing opinion until recent times. While it is true that none of the authors quoted above had actually examined any of the reptiles carried in the dance, their conclusions have occasionally been given weight by the observations of trained herpetolo-

<sup>6</sup>G. A. Dorsey, “Indians of the Southwest,” p. 154. Santa Fe, 1903.

<sup>7</sup>C. F. Lummis, *Sunset Magazine*, 52: 32, 1924.



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FIG. 1. THE START OF A SNAKE HUNT

MEMBERS OF THE SNAKE SOCIETY AT ORAIBI LEAVING THEIR KIVA TO HUNT FOR SNAKES ON ONE OF THE DAYS PRECEDING THE PUBLIC DANCE. NOTE THE LONG DIGGING STICKS WHICH THEY CARRY.

gists. At the Walpi performance of 1883, for example, an army doctor named H. C. Yarrow entered the snake kiva just before the public dance, selected a large rattler at random, and "upon prying its mouth open, he found the fangs intact and of large size."<sup>8</sup> Furthermore, at the conclusion of this same ceremony, two rattlesnakes were captured and sent to the National Museum where Dr. S. W. Mitchell reported that "Their fangs had not been disturbed. . . ."<sup>9</sup>

The view that the reptiles are not defanged received additional support from Klauber after he had witnessed the Snake Dance at Mishongnovi in 1931. During this performance, Klauber and his son independently noted two rattlesnakes (*Crotalus confluentus confluentus*) which revealed their fang sheaths when their mouths were open, an indication that the fangs had neither been

<sup>8</sup> C. Mindeleff, *Science*, 8: 12, 1886.

<sup>9</sup> *Idem*. It should be noted that no proof was ever offered to show that the rattlers examined by Yarrow and Mitchell had actually been used in the dance.



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FIG. 2. INSIDE A SNAKE KIVA

YOUTHFUL MEMBERS OF THE SNAKE SOCIETY  
GUARDING THE REPTILES WHICH ARE SOON TO BE  
USED IN THE SNAKE DANCE.

removed nor cut short. On the basis of these personal observations, coupled with a thorough examination of the publications pertaining to the subject, Klauber concluded that "the case for the non-disturbance of the fangs is proven. . . ."<sup>10</sup>

Nevertheless, in the light of a mass of recent data, it is no longer possible to regard the issue as closed; for it can now be demonstrated that the Hopi do, at least on some occasions, defang their snakes. The first writer to uphold this viewpoint was E. S. Curtis, who expressed considerable surprise at the lack of skepticism shown by many students of the Hopi, and who quoted an experienced snake performer to the effect that the rattlesnakes are "rendered absolutely harmless by the removal of their fangs."<sup>11</sup> During the course of a field trip to the Hopi in the summer of 1932, I encountered my first bit of evidence in support of Curtis' position. Together with other members of the party of which I was a member, I was present at Oraibi when an elderly native, formerly enrolled in the Snake Society, voluntarily began to deprecate the ceremony because it failed to bring rain and because the snakes were defanged. In pantomime the speaker showed us how a snake's open mouth was rubbed up and down against something that protruded upward from the ground. At the time very little attention was paid to the old man's remarks because he spoke so little English that we could not be absolutely certain of his meaning, and because he had long been a convert to Christianity and there was a possibility that he was seeking to discredit his former religion.

Several years later this little episode took on an added significance when two similar reports of defanging were brought to the writer's attention from

<sup>10</sup> L. M. Klauber, *op. cit.*, p. 39.

<sup>11</sup> E. S. Curtis, "The North American Indian," 12: 136, 1922.

other sources. Once again the information came from Christian Hopi, who, having abandoned their native faith, were now seeking to malign it. However, both men were giving their testimony to an official of the Office of Indian Affairs, and inasmuch as some of their evidence has since been corroborated by an unimpeachable investigator, it may well be that there are elements of truth in their depositions. One witness explained that he had been greatly frightened when he was ordered to catch the first snake during his novitiate, but that the snake chief had later revealed "that they had extracted the snake's fangs, teeth and poison sacs before calling him up to bag it."<sup>12</sup> The speaker then went on to say that the operation was secretly performed with a hoe-like instrument, and that the poisonous snakes were examined prior to the dance to make sure that their fangs had not grown back.

A second witness, testifying in the same vein, gave additional details. According to his story, when he was a novice an experienced snake man named Satsiki had instructed him "to place his snake stick with the butt end in the ground, and the flat end in the air. Satsiki then seized the snake just back of the head, squeezed its jaws, to force them open, and rubbed the jaws along the flat side of Deponent's snake stick, thus breaking out the snake's fangs and teeth, and squeezing out the poison sacs. He then told Deponent: 'This is the way we treat the snakes, so as not to be bitten.'<sup>13</sup> Later on in his testimony, this witness also claimed that the snakes are examined before the dance and are again defanged if necessary.

Such statements by renegades from their native religion might well be dismissed as biased and untrustworthy were it not for the fact that they have recently received striking confirmation in at least



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FIG. 3. THE ORAIBI SNAKE DANCE

IN THIS VIEW THE CARRIER IN THE FOREGROUND IS STILL DANCING WITH A SNAKE AT HIS LIPS, WHILE THE YOUNG GATHERER AT THE LEFT IS ABOUT TO PICK UP A REPTILE WHICH ANOTHER DANCER HAS RELEASED.

one instance. At the close of the Chimpovoy Snake Dance on August 24, 1932, C. M. Bogert, now assistant curator of herpetology at the American Museum of Natural History, followed one of the performers and watched him liberate his quota of reptiles at a shrine. As soon as possible after the dancer had withdrawn, Bogert hurried to the spot and succeeded in capturing a single rattler which had not yet escaped into the open. His published account of this adventure is directly pertinent to our discussion:

In the sanctum of a gully not far from the shrine, a stop was made to examine the rattlesnake in case anything were to happen which might not later allow us the opportunity to do so. From Klauber's observations, and from the accounts of most ethnologists (except Curtis . . .) I fully expected to find the venom apparatus intact. Therefore, it was something of a surprise, upon prying the snake's mouth open with a pencil, to find the fangs entirely lacking and obviously removed. With the object of learning something regarding the condition of the venom glands, pressure was applied with the thumb and finger to the proper region, but no venom, at least none recognizable as such, was forced into the mouth. Of course, with the fangs removed, it would be difficult to observe and identify a discharge of venom.<sup>14</sup>

<sup>14</sup> C. M. Bogert, *Copeia*, No. 4, 1933, p. 220. A fuller account of this entire affair has recently been published by Bogert in *Natural History*, 47: 276-283, 1941.

<sup>12</sup> Taken from a transcription of a report in the files of the Office of Indian Affairs, 1920.

<sup>13</sup> *Idem*.



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FIG. 4. AN EARLY STAGE IN THE HOPI SNAKE DANCE AT ORAIBI  
MEMBERS OF THE SNAKE SOCIETY (ON THE LEFT) AND OF THE ANTELOPE SOCIETY (ON THE RIGHT)  
ARE SINGING IN UNISON. AT THIS STAGE THE REPTILES ARE HIDDEN WITHIN THE COTTON-WOOD  
SHELTER AT THE EXTREME RIGHT.



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FIG. 5. THE ORAIBI SNAKE DANCE IN PROGRESS  
THE CARRIER IN THE CENTER STILL HOLDS A SNAKE TO HIS LIPS, WHILE THE CARRIER AT THE LEFT  
IS ABOUT TO RELEASE A SNAKE WITH WHICH HE HAS FINISHED DANCING. SPECTATORS WATCH FROM  
THE ROOF TOPS OF THE NEAR-BY BUILDINGS.

In order to have his own examination made in the field confirmed, Dr. Bogert later sent the snake to Klauber. Under date of September 16, 1932, Klauber sent a letter to Bogert which reads in part:

I pickled the snake last night and found as you had supposed that apparently not only the functional fangs had been removed, but all of the rudimentary fangs as well. In fact, it would appear that the sockets in the maxillary which normally hold the functional fangs, were completely extirpated. This has been done with a knife as indicated by cuts rather than tears, and on the whole it was rather well done, if you forget the snake's feelings in the matter. . . .<sup>15</sup>

Thus, within a period of nine months after he had concluded that "the case for the non-disturbance of the fangs is proven," did Klauber cheerfully admit that the opposite was undoubtedly true in at least one instance.

Of course, as Bogert is careful to point out, the discovery of a single defanged rattler does not imply that all the dangerous reptiles are defanged; nor must we forget that Yarrow and Mitchell had found rattlesnakes which had not been operated upon. In the latter instance, however, there is still the possibility that the Indians had resorted to the simpler method of rendering the snakes harmless by "milking" them of their poison. It is significant that even at the time when Klauber was convinced that the Hopi did not defang their snakes, he had indulged in an interesting bit of conjecture on this score. "To my mind," he wrote, "the removal of the venom . . . would be so easy and safe, and so much more difficult to detect, that this is a more plausible explanation of how the Indians handle the snakes so fearlessly and with so few adverse effects. . . ."<sup>16</sup> He then

goes on to state that the removal could readily be accomplished by letting the reptiles strike at some soft object, or by manipulating their venom glands.

This hypothesis finds support not only in the testimony of the Christianized natives cited above, but also in the words of a faithful Hopi. In an interview with Stephen in 1885, Wiki, an orthodox Hopi official, who had long served as Antelope chief of Walpi, remarked, "The snake whip is used to cause the snake to strike at it repeatedly and exhaust the venom. As soon as the venom sac is empty the snake straightens out, and he is then seized."<sup>17</sup> Thanks to Wiki's authoritative testimony, it is plainly evident that even if the Hopi do not invariably defang dangerous reptiles, they may still render them harmless by a "milking" process.

Armed with the knowledge that the Hopi do, at least occasionally, take pains to make their snakes safe, we may now venture to read somewhat between the lines in a few of the earlier publications, in order to point out the strong probability that the members of the Snake Society have long conspired to hide their treatment of snakes from white observers as well as from their fellow tribesmen. To begin with, it should be explained that whereas the Hopi have sometimes permitted spectators to watch nearly the entire schedule of rites, they have usually managed to secure privacy just before the public dance begins, and on the occasion of snake hunts. For example, Bourke reports that he and his companions were allowed ready access to the snake kiva at Walpi in 1881, but just as the public exhibition was about to begin one of the old men persuaded them to leave lest their clothing be stained by the paint which the dancers were apply-

<sup>15</sup> C. M. Bogert, *Copeia*, No. 4, 1933, p. 220. It should be noted that the cuts which Klauber mentions might possibly have been inflicted by the metal-bladed digging sticks which the Snake men carry when they go to hunt for snakes on four successive days prior to the public dance (see Fig. 1). In recent years the men often carry knives on these occasions.

<sup>16</sup> L. M. Klauber, *op. cit.*, p. 41.

<sup>17</sup> A. M. Stephen, *Hopi Journal* (E. C. Parsons, ed.), New York: Columbia University Press, 1936, p. 585. The Antelope Society, of which Wiki was the chief, is a partner of the Snake Society, and combines with it in the performance of the rites. See Fig. 4.

ing to their bodies.<sup>18</sup> To any one who has ever lived in a Hopi pueblo the old man's ruse is perfectly clear, for the one thing to which elderly Hopi are most completely indifferent is dirt of any description!

Even more revealing are the subterfuges employed to keep spectators from witnessing the snake hunts. Uninitiated tribesmen are kept away by a stock device of Hopi ceremonialism. They are warned that those who trespass on the hunting grounds will either be stricken with fatal swellings (a disease supposedly controlled by the snake cult), or else they will be forced to join the Snake Society, a contingency which is dreaded by the average Hopi. As for white men, either they are simply requested not to come into the neighborhood of a snake hunt, or else they are told that the presence of strangers will interfere with the success of the searchers. The language in which Stephen was forbidden to join a party of hunters is particularly significant. "They say it will be bad for the young snake members who are to catch their first snakes to-day," he comments.<sup>19</sup> It is only when we recall the vivid testimony of the Christian deponents (*vide supra*) that we can fully appreciate why the presence of a white man would have been "bad" for the novices.

Perhaps the strongest "between-the-lines" testimony of all is to be found in the Reverend H. R. Voth's account of an incident that occurred at Oraibi in 1896. When it was learned that Voth was bent on joining a hunting party, the older snake men became greatly upset. At first they merely insisted that his presence would make the search unsuccessful; then they literally begged him not to go along; and finally they offered to strike a bargain with him. As Voth relates their terms, "I could see and hear everything else, only I should do them

the favor and not go with them on the snake hunt"; and when Voth agreed to these conditions, "a big burden seemed to have rolled from their hearts."<sup>20</sup>

On a different occasion, however, Mr. Voth did actually accompany a group of hunters from Oraibi. Unfortunately, he was afraid that he would not be able to keep up with the more vigorous searchers, so he elected to follow the old snake chief who was "entirely blind in one eye, the other one being very poor," and another man who was also "old and feeble, and also nearly blind."<sup>21</sup> Needless to say, Voth saw no snakes captured, and we may imagine the laughter of the younger snake men at the prospect of Voth's endeavor to discover their secrets by following a pair of feeble, dim-sighted old men.

By one means or another the Hopi Indians have generally succeeded in preventing outsiders from watching their snake hunts at close range. Only Stephen has published an eye-witness account, but it is evident from his report that the snake which he saw taken had first been found by a distant hunter who had then called the rest of the party to him.<sup>22</sup> Had this man so desired, he could have operated on the creature before summoning the others to watch its capture—a trick which experienced Snake men apparently play on novices.

In one instance Dr. Fewkes showed Kopeli, head chief of the Walpi Snake Society, a hole in which he had noticed a rattlesnake, but Kopeli flatly refused to dig it out in his presence. Fewkes attributed Kopeli's refusal to the great care with which he was trying to "preserve this one feature of the ceremony, the capture of the reptile in the open";<sup>23</sup>

<sup>20</sup> H. R. Voth, "The Oraibi Summer Snake Ceremony," p. 292. Chicago: Field Columbian Museum, 1903.

<sup>21</sup> *Ibid.*, p. 290.

<sup>22</sup> Quoted in Klauber, *op. cit.*, pp. 68-69. I have not had an opportunity to check the original source.

<sup>23</sup> J. W. Fewkes, *op. cit.*, p. 277.

<sup>18</sup> J. G. Bourke, *op. cit.*, p. 151.

<sup>19</sup> A. M. Stephen, *op. cit.*, p. 608.

but somewhat naively, Fewkes overlooked the possibility that Kopeli might actually have been afraid of a genuinely dangerous rattler. In support of the more realistic interpretation of this episode, we have Voth's explicit statement that "At any other time except during the ceremonial days, the members of the Antelope and Snake Fraternity seem to be just as much afraid of a rattlesnake as other people."<sup>24</sup> On a number of occasions Voth challenged snake men to pick up rattlers which he had discovered, but this "they very emphatically refused to do, saying that if they . . . touched a snake while they were not 'assembled' they were just as liable to be bitten as any other person."<sup>25</sup>

As for the Antelope men, their fear of untreated rattlers may be so great as to border on the ludicrous. In one case Voth dared a friend of his, an Antelope Society member, to pick up a rattlesnake. When he refused, Voth struck the snake a blow, picked it up and began to pursue his friend who "dashed away and screamed, evidently in genuine fear, crawled . . . under a wire fence, and ran away as fast as his legs would carry him. . . ."<sup>26</sup> It might be argued, of course, that the person whom Voth had so badly frightened was an Antelope man, and as such he may not have had the skill in handling reptiles that the snake men learn to acquire; yet, had this same individual been handed a rattlesnake by one of the gatherers at the public spectacle, he would have held it with apparent nonchalance as he sang and rattled in the fashion prescribed for his group.

#### SUMMARY AND CONCLUSION

In the course of the Hopi Snake Dance the participants handle with im-

punity several varieties of reptiles including the prairie rattlesnake, whose bite may have very serious consequences. Nevertheless, dancers are rarely stricken and never fatally injured. This immunity results neither from the use of stupefying drugs nor from the employment of therapeutic immunizers or antidotes. Instead, the safety of the performers is achieved partly by making the snakes docile through careful handling in captivity, and partly by resorting to such devices as defanging and emptying the venom glands. Although the latter practices have been frequently denied by former writers, a review of all the evidence available clearly points to the conclusion that the Hopi can, and occasionally do perform such operations; perhaps with the metal-tipped digging sticks and feather "whips" which are part of the Snake Society's equipment.

It would be unwarranted, in the present state of our knowledge, to claim that all the rattlesnakes used in the ceremony are made harmless; but on the other hand, it can no longer be maintained that the snakes are never treated or that the Hopi dancers are recklessly indifferent to the dangers of venomous snake bites. In all likelihood, future researches will reveal that the major operations are performed systematically, according to some pattern of ritual procedure that has not yet been discovered. Indeed, it is already reasonably certain that the greatest care is exercised to render rattlers innocuous on those occasions, like snake hunts, when novices are about to handle them for the first time. In my opinion this is done both to protect the tyros from harm, and to inspire them with the necessary confidence so that they may perform in public with that air of calm indifference to great danger which makes the snake dancer a hero to his own people, and an object of awe and admiration in the eyes of white spectators.

<sup>24</sup> H. R. Voth, *op. cit.*, p. 357.

<sup>25</sup> *Ibid.*, p. 358.

<sup>26</sup> *Idem.*

# OCCUPATIONS OF EMINENT MEN

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OCCUPATION is an important consideration in studies of eminent men for two reasons. In the first place, the achievement for which a man gains recognition is usually directly associated with some vocation or occupation, whether or not the person is gainfully employed. All men, including those socially recognized, can be classified according to the field of endeavor in which they have been active. In the second place, and of far more importance, is the fact that occupations differ in prestige and in opportunities for eminence possessed by persons engaged in them. It is the purpose of the present discussion to summarize the most important available information on the vocational affiliations of both historical and contemporary notable men and women; and to present some new data on chances for eminence possessed by persons in certain occupations.

## OCCUPATION AND HISTORICAL EMINENCE

The most serviceable data for studying the relationship between occupation and historical eminence are those from the studies of amount of space occupied by the biographies of men famous in different occupations. Cattell's list showed that the outstanding occupations for the one hundred most eminent persons of history, as analyzed forty years ago, were sovereign, poet and philosopher.<sup>1</sup> Table I presents a detailed classification.

Because several of these one hundred persons were extremely versatile, matters will be clarified somewhat if a tabulation is made of the actual number of times each vocational class appears in the group. This is done in Table II. The most frequent occupation is that of philosopher, with statesmen close behind,

<sup>1</sup> J. M. Cattell, *Popular Science Monthly*, 1903, 62, 369-377.

TABLE I

MAJOR OCCUPATIONS OF THE 100 MOST EMINENT PERSONS OF HISTORY

Occupation	N
Ruler .....	15
Poet .....	15
Philosopher .....	11
Statesman .....	7
Religious founder or reformer .....	5
Writer (essayist, historian, scholar) .....	5
Scientist .....	4
Philosopher and scientist .....	4
Statesman and writer (essayist, historian, scholar) .....	4
Soldier and statesman .....	3
Theologian .....	2
Soldier and ruler .....	2
Painter .....	2
Philosopher and statesman .....	2
Playwright .....	1
Playwright and poet .....	1
Philosopher and writer (essayist, historian, scholar) .....	1
Explorer .....	1
Poet and novelist .....	1
Admiral .....	1
Poet and miscellaneous writer .....	1
Painter, sculptor, architect and engineer ....	1
Statesman and scientist .....	1
Philosopher and ruler .....	1
Scientist, painter, sculptor, architect and engineer .....	1
Composer .....	1
Poet, dramatist and philosopher .....	1
Philosopher, religious leader and statesman ..	1
Theologian and statesman .....	1
Scientist, theologian and philosopher .....	1
Statesman, soldier and writer (essayist, historian, scholar) .....	1
Statesman, scientist and philosopher .....	1
Statesman, poet and writer (essayist, historian, scholar) .....	1

TABLE II

FREQUENCY OF AFFILIATION OF THE 100 MOST EMINENT PERSONS OF HISTORY WITH MAJOR OCCUPATIONS

Occupation	N
Philosopher .....	23
Statesman .....	22
Writer (poet, novelist, dramatist) .....	21
Ruler .....	18
Writer (essayist, historian, scholar) .....	13
Scientist .....	12
Religious founder and reformer .....	6
Soldier .....	6
Theologian .....	4
Painter .....	4
Architect .....	2
Engineer .....	2
Sculptor .....	2
Admiral .....	1
Composer .....	1
Explorer .....	1

"creative" writers (poets, novelists, dramatists) third, and rulers fourth. Among the three general groups, executive, intellectual and artistic leaders, the executive and intellectual leaders are almost equally represented, while artistic notables are considerably less numerous. Intellectual leaders (philosophers, writers—essayists, historians, scholars, scientists, theologians) represent 52 affiliations. Executive leaders (rulers, statesmen, soldiers, engineers, explorers, admirals) represent 50 affiliations. Art represents 29 affiliations (poets, novelists, dramatists, painters, sculptors, composers). There are some additional vocations more difficult to classify, which would alter the rank order of the main groups. Architects combine the qualities of engineers and artists. And religious founders and reformers also offer some difficulties of classification. They exhibit extreme leadership, and some of them have proved to have exceptional executive talent. But they also have been ideological leaders. Consequently, we may conclude that executive and intellectual pursuits are about equal in being the outstanding vocations for world eminence in the historical sense, and are considerably superior in this respect to artistic pursuits.

Castle's study of the occupations of the eminent women of history discloses the fact that the literary occupation was far in the lead, while sovereigns ranked fourth, other politically influential women ranked tenth, persons eminent in religion ranked third, and scholars ranked ninth,<sup>2</sup> facts which indicate only a small amount of agreement between this study and the study based on Cattell's list. Castle's complete occupational data are presented in Table III.

Another study of interest is that of Huntington, based on 8,576 European persons of eminence who lived between

<sup>2</sup> C. S. Castle, *Archives of Psychology*, No. 27, 1913.

TABLE III

OCCUPATIONS OF THE EMINENT WOMEN OF HISTORY\*

Occupation	N
Literature .....	337
Marriage .....	87
Religion .....	64
Sovereign .....	59
Actress .....	56
Music .....	49
Birth .....	39
Mistress .....	29
Scholar .....	20
Political influence .....	19
Artist .....	17
Philanthropy .....	12
Tragic fate .....	11
Heroine .....	10
Motherhood .....	10
Reformer .....	9
Dancer .....	6
Literary character .....	6
Patron of learning .....	6
Beauty .....	6
Education .....	3
Revolutionist .....	2
Misfortune .....	2
Traveler .....	2
Adventuress .....	2
Physician .....	2
Fortune teller .....	1
Criminal .....	1
Conjugal devotion .....	1
	863

\* Castle, *op. cit.*, p. 40.

1600 and 1900 A.D. The classification of occupations and the results are somewhat different from those already mentioned. Persons famous in politics and revolution, war and adventure, "inheritance without merit" and business composed about 29 per cent. Writers of all sorts were grouped together so that the exact division of the artistic and intellectual pursuits remains rather indefinite, but about the same per cent. of the cases were in the fields of "creative" literature and art. The intellectual group thus dominated, with about 9 per cent. famous in religion and philanthropy, about 3 per cent. in philosophy and education, about 13 per cent. in science, nearly 10 per cent. in history and economics and at least 5 per cent.—perhaps more—in the writing of essays and criticism. About one half of one per cent. were classed as freaks, that is, were notorious but without merit or achievement.<sup>3</sup>

From Maas's study of 4,421 German leaders who lived between 1700 and 1910

<sup>3</sup> Ellsworth Huntington, "The Character of Races," p. 235. New York, 1924.

A.D. we have data that discloses the occupational distribution of eminent men of one country. The degree of eminence is not as great as that of Cattell's and Castle's limited groups, but the studies are roughly comparable. Maas distinguished seventeen vocational classes, five being in the artistic sphere, four in the practical sphere and eight in the intellectual sphere. Of the total cases the largest average for the professions was in the intellectual sphere, especially among theologians and philologists. Persons in practical fields were definitely fewer than artistic persons, which was contrary to the facts for the lists of most eminent men mentioned above. Among the artists Maas included some of the more serious writers that Cox classified as intellectuals, and he did not include rulers. The complete percentages are given in Table IV.

TABLE IV  
EMINENT GERMANS CLASSIFIED ACCORDING TO  
VOCATIONAL GROUPS\* (AFTER MAAS)

Vocation	Num- ber	Per- centage	Rank Order
<i>Artistic Sphere</i>			
1. Poets .....	290	6.66	8
2. Writers .....	202	4.57	10
3. Musicians .....	193	4.36	12
4. Creative artists ...	338	7.64	4
5. Stage artists .....	90	2.04	15
Total .....	1,113	25.17	(2)
<i>Intellectual Sphere</i>			
6. Theologians .....	504	11.40	2
7. Philologists .....	507	11.47	1
8. Historians .....	301	6.81	6
9. Pedagogues .....	118	2.57	14
10. Legal profession ..	323	7.31	5
11. Medical men .....	198	4.46	11
12. Exact scientists ...	179	4.05	13
13. Natural scientists .	229	5.18	9
Total .....	2,359	53.37	(1)
<i>Practical Sphere</i>			
14. Statesmen .....	498	11.26	3
15. Agriculturists .....	69	1.56	17
16. Military men .....	295	6.67	7
17. Merchants .....	87	1.97	16
Total .....	949	21.46	(3)
Grand Total ....	4,421	100.00	-

\* Adapted from P. A. Sorokin, C. C. Zimmerman and C. J. Galpin, "A Systematic Source Book in Rural Sociology," Volume III, pp. 312-313. Minneapolis, 1932.

#### OCCUPATIONS OF CONTEMPORARY EMINENT PERSONS

The most recent analysis of the occupations of contemporary notable Americans is for the 1938-1939 "Who's Who in America." Following the general classifications of the United States census the leaders have been classified according to five main occupational fields and some forty specific occupational classes, as shown in Table V.<sup>4</sup> Professional workers are in the lead, followed by proprietorial workers, protective service workers, farmers and farm managers and clerical workers, while all other kinds of workers, including craftsmen, machine operatives, domestic service workers and laborers are entirely unrepresented. The most important specific occupations, in order, were college and university administration and teaching, writing and editing, law, religion, medicine and government service. Other educators; financiers, insurance agents and real estate agents; and engineers also rank well up in the list. These results agree in general with several other studies.<sup>5</sup>

TABLE V  
OCCUPATIONAL DISTRIBUTION OF PERSONS LISTED IN  
"WHO'S WHO IN AMERICA," 1938-39

Occupation*	Num- ber	Per- cent- age	Rank Order
Professional and Semi-professional Workers ....	24,626	78.3	(1)
Professional .....	24,284	77.2	((1))
Actors .....	155	.5	21.5
Architects .....	253	.8	18
Artists and art teachers	900	2.9	12
Authors, editors and reporters .....	4,388	14.0	2

<sup>4</sup> Also see Fritz Giese, "Die öffentliche Persönlichkeit," *Zeitschrift für angewandte Psychologie*, Supplement, 44, 1923, for an earlier detailed tabulation.

<sup>5</sup> For example, G. R. Davies, *Quarterly Journal of the University of North Dakota*, 4: 225, 1914; Scott Nearing, *Popular Science Monthly*, 85: 189-199, 1914; and *Scientific Monthly*, 2: 57, 1916.

Chemists, assayers, metallurgists .....	124	.4	23.5
Clergymen .....	3,006	9.5	4
College presidents, pro- fessors and instruc- tors .....	4,996	15.9	1
Dentists .....	30	.1	28.5
Engineers .....	1,165	3.7	10
Lawyers and judges ..	3,552	11.3	3
Musicians and music teachers .....	679	2.2	14
Osteopaths .....	13	.04	32
Pharmacists .....	2	.006	36
Physicians and sur- geons .....	2,090	6.6	5
Social and welfare workers .....	145	.5	21.5
Teachers (not else- where classified) ..	1,333	4.2	8
Trained nurses .....	2	.006	36
Veterinarians .....	27	.1	28.5
Other professional workers .....	1,424	4.5	7
<i>Semi-professional work- ers</i> .....	342	1.1	((2))
Dancers, showmen and athletes .....	20	.1	28.5
Designers and drafts- men .....	40	.1	28.5
Other semi-professional workers .....	282	.9	16.5
<i>Farmers and Farm Manag- ers</i> .....	132	.4	(4)
<i>Proprietors, Managers and Officials, Except Farm</i> Government officials ....	6,124	19.5	(2)
Other specified managers and officials .....	2,060	6.5	6
Proprietors, managers and officials, not otherwise classified, by industry	230	.7	19.5
Mining .....	119	.4	23.5
Construction .....	50	.2	25
Manufacturing .....	838	2.7	13
Transportation, com- munication and utili- ties .....	290	.9	16.5
Trade .....	211	.7	19.5
Finance, insurance and real estate .....	1,273	4.0	9
Personal service .....	13	.1	28.5
Miscellaneous indus- tries and services ..	1,040	3.3	11
<i>Clerical, Sales and Kindred Workers</i> .....	27	.1	(5)
Bookkeepers, account- ants, cashiers and ticket agents .....	19	.1	28.5
Secretaries, stenogra- phers and typists ..	6	.02	33
Other clerical and kindred workers ...	2	.006	36
<i>Protective Service Workers</i> Policemen, sheriffs and marshals .....	545	1.7	(3)
4	.012	34	
Soldiers, sailors, marines and coast guards ....	541	1.7	15
Total .....	31,454	100.0	

\* Occupational classifications follow *Classified Index of Occupations, and Alphabetical Index of Occupations and Industries*, Washington, 1940.

The situation in some other countries is similar to that in the United States. Data for Germany, Denmark, Japan and India are given in Table VI. There are

marked differences between these countries, Germany having a larger proportion of persons in the mental sciences than in any of the four other comprehensive fields, but for the other countries most prominent persons are found in practical vocations. In Germany the arts were far more important than in the other countries, twice as important as in Denmark, about 29 times as important as in Japan, and about 23 times as important as in India. In Japan practical life embraced more than 60 per cent. of all prominent persons, and in India more than 56 per cent. were in administration alone. In Japan commerce was the most important single occupation, followed, very significantly, by military affairs; in Denmark the most important occupation was administration, with military affairs also ranking second; in Germany literature was the leading vocation, followed by medicine.

Germany and Denmark had a fairly similar distribution, and that of India resembles that of Japan. Thus the two European countries were quite similar, as were the two Asiatic empires, but the Asiatic and European countries were quite different. This fact may be due to some extent to the manner of selection of the persons in the respective lists, which may be under different auspices in different countries and used for different purposes. But a large part of the difference is a function of the difference between cultures and social organizations. This is particularly marked in the case of Japan, with its emphasis on commerce, military affairs and administration and its small interest in the arts, in philosophy and in various intellectual and scientific professions so important in Europe and America.

The distribution for the United States, to the extent that the lists are comparable, resembles those of Germany and Denmark more closely than it does those of Asia. The outstanding differences

TABLE VI  
OCCUPATIONAL DISTRIBUTION OF PROMINENT PERSONS IN GERMANY, DENMARK, JAPAN  
AND INDIA DURING THE DECADE 1920-1930\*

Occupation	Germany		Denmark		Japan		India	
	Per cent.	Rank	Per cent.	Rank	Per cent.	Rank	Per cent.	Rank
<i>Art</i> .....	23.99	3	12.28	4	.85	5	1.03	5
Painting .....	6.29	1	3.85	9.5	.35	20.5	....	...
Sculpture .....	1.18	24	1.12	21	.05	28.5	....	...
Architecture .....	1.50	19	1.75	17	.05	28.5	.16	21
Music .....	4.92	9	2.94	13	.23	22.5	.60	11
Literature .....	8.10	2	2.62	14	.17	25.5	.27	16.5
<i>Mental Science</i> .....	32.09	1	21.96	2	15.13	2	12.57	2
Theology .....	5.53	5	3.85	9.5	.41	16	.16	21
Law .....	5.07	7	7.94	6	6.81	5	6.21	3
Philosophy .....	1.77	18	.21	30	.41	18	.27	16.5
Philology .....	4.83	10	1.22	19	.47	16	2.25	9
Pedagogy .....	3.68	11	5.60	7	5.03	6	2.97	8
History .....	6.55	4	1.54	18	.71	14	.11	23.5
Mathematics .....	.96	27	.45	25.5	.17	25.5	.16	21
Political Economy .....	2.70	16	1.15	20	1.12	13	.44	13
<i>Natural Science</i> .....	17.99	4	20.04	3	14.71	3	6.98	3
Medicine .....	7.54	3	8.68	4	7.64	4	2.75	6
Cosmology .....	1.06	25	.49	24	.17	25.5	....	...
Chemistry .....	2.12	17	1.05	22	.41	18	.05	26.5
Physics .....	1.33	22	.38	28.5	.17	25.5	.11	23.5
Mineralogy .....	1.21	23	.42	27	1.30	11.5	....	...
Zoology .....	.90	29.5	.38	28.5	.23	22.5	....	...
Botany .....	.94	28	.56	23	....	...	....	...
Agriculture .....	2.90	14	8.08	5	4.79	7.5	2.07	4
<i>Technology</i> .....	1.55	5	2.69	5	4.79	4	3.46	4
Construction .....	1.35	21	2.59	15	4.79	7.5	3.41	5
Smelting .....	.20	32	.10	31	....	...	.05	25.5
<i>Practical Life</i> .....	24.38	2	43.03	1	64.52	1	76.06	1
Administration .....	4.98	8	10.31	1	13.98	3	56.16	1
Politics .....	3.21	13	3.22	12	4.73	9	13.64	2
Military affairs .....	3.43	12	9.30	2	15.52	2	2.80	7
Crafts .....	.67	31	2.55	16	.59	15	....	...
Commerce .....	2.87	15	9.26	3	24.38	1	1.76	10
Industry .....	.90	29.5	3.43	11	3.67	10	.22	18.5
Publicity .....	5.74	6	4.51	8	1.30	11.5	.33	15
Geography, Exploration ..	1.40	20	.45	25.5	....	...	.22	18.5
Organization, Propaganda ..	1.02	26	....	...	.35	20.5	.55	12
Miscellaneous .....	.16	33	....	...	....	...	.38	14

\* Glese, *op. cit.*, pp. 14, 236.

between the United States and German distributions are in the arts, military affairs and agriculture, where the German proportions were larger; and in law and religion, where the United States stands out. The United States resembles Denmark in art, is far behind in agriculture and military affairs, and far ahead in religion and law. In many of the specific mental and natural sciences no direct comparisons are possible, because of the classification employed for the United States. College and university education overlaps on these scholarly professions to such an extent that the distributions for Germany and Denmark may well resemble that of the United

States, but India and Japan lag in everything except practical vocations, in only a few of which they are heavily represented.

#### CHANCES FOR EMINENCE IN EACH OCCUPATION

The data on occupational distribution of prominent persons are not very significant unless the occupational distribution of the total population is also taken into consideration. Although the matter has received some attention,<sup>6</sup> numerous obstacles stand in the way of comparing eminent men and the general population in regard to occupational distribution.

<sup>6</sup> Cf. Giese, *op. cit.*, pp. 87-92.

In the first place, it is impossible to obtain reliable occupational distributions for past historical periods. Secondly, there is little agreement between existing classifications of occupations of eminent persons and those of the general population, except where parallel categories are deliberately used. And if very crude classifications are used for both the general population and the list of prominent persons, the results are rather meaningless. Again, the inclusion of all classes of people in the same general occupation does not give a correct impression of the chances for eminence of an individual in the more responsible and influential administrative positions in the general field. For example, almost all the persons listed in "Who's Who in America" from the field of transportation are from the highest administrative and executive levels, and it is a question if all persons employed in transportation should be compared with these selected persons from a selected part of the total group gainfully employed in transportation. What needs to be done is to have both the general and the most socially recognized populations classified according to the same functional classification, each class being determined by the general social function and by the specific contribution to the general social function. It would also be advisable to base the inclusiveness of the general functional groups upon the chances for each individual to climb into the most favored circles (administration and ownership) of the general functional group of which he is a member.

The available data from published studies are far short of this ideal. Only the crudest sort of comparisons can be made for the occupations of historical personages. Philosophy stands out more than any other profession in the production of the most illustrious persons of history, since there have been few professional philosophers and philosophical

writers. Of the relatively small number of persons in this profession during the period of history, a relatively large proportion have attained the very greatest fame. Writers and scientists also stand out historically, as do rulers, artists and musicians. The religious vocation is not heavily represented, according to its numbers, although the most eminent personages include a high proportion of religious founders and reformers. Engineering also does not seem to have provided many eminent personages in proportion to the number of people engaged in such pursuits during the development of advanced civilizations. But most striking is the tremendous inferiority of the occupations that make up the bulk of the population in other historical periods—craftsmen and artisans, personal and domestic servants, tradesmen, farmers and peasants and other manual laborers.

Among famous women of history the vocation of literature is of very great importance, and sovereignty is about equal to it. Indeed, sovereignty stands alone in the lead, if we consider that few women who were sovereigns in their own right have appeared in history. Acting, music, scholarship and art also have provided outstanding opportunities for fame. In religion women seem to have a proportionately better record than men, since the traditional role of women in most societies has kept them from positions of leadership.

In general, Maas's data for Germany bear out the same conclusions.<sup>7</sup> The arts and the intellectual vocations obviously surpass the practical vocations in per capita production of prominent persons, when we consider the number of people working in various vocations. And of the practical vocations, statesmen have an advantage; but agriculturists, military men and merchants are at a severe disadvantage, and craftsmen, artisans, industrial workers, miners, fish-

<sup>7</sup> Cf. Table IV.

TABLE VII  
NUMBER OF PERSONS LISTED IN "WHO'S WHO IN AMERICA, 1938-39" PER MILLION OF EMPLOYED  
POPULATION, 14 YEARS OLD AND OVER, 1940

Occupational Class	Number of persons in "Who's Who in America, 1938-39"*	Number of persons 14 years old and over employed 1940†	Number in "Who's Who in America" per 1,000,000 of the employed population	Rank order
Professional and Semiprofessional Workers ....	24,626	3,345,048	7,361.9	(1)
Professional .....	24,284	2,881,594	8,427.3	((1))
Actors .....	155	11,692	13,256.9	6
Architects .....	253	19,899	12,714.2	7
Artists and art teachers .....	900	51,985	17,312.7	5
Authors, editors and reporters .....	4,388	70,059	62,632.9	2
Chemists, assayers, metallurgists .....	124	55,371	2,239.4	18
Clergymen .....	3,006	133,449	22,525.5	3
College presidents, professors and instructors .....	4,996	75,007	66,605.3	1
Dentists .....	30	71,414‡	420.1	27
Engineers .....	1,165	244,558	4,763.7	13
Lawyers and judges .....	3,552	177,643	19,995.2	4
Musicians and music teachers .....	679	129,256	5,253.1	12
Osteopaths .....	13	5,071‡	256.4	29
Pharmacists .....	2	78,709‡	25.4	32
Physicians and surgeons .....	2,090	164,649	12,693.7	8
Social and welfare workers .....	145	69,677	2,081.0	20
Teachers (not elsewhere classified) .....	1,333	1,030,001	1,294.2	22
Trained nurses .....	2	355,786	5.6	36
Veterinarians .....	27	10,998‡	2,455.0	16
Other professional workers .....	1,424	126,370	11,268.5	9
Semiprofessional Workers .....	342	463,454	737.9	((2))
Dancers, showmen and athletes .....	20	31,147	642.1	24
Designers and draftsmen .....	40	100,925	396.3	28
Other semiprofessional workers .....	282	331,382	851.0	23
Farmers and Farm Managers .....	132	5,143,614	25.7	(4)
Proprietors, Managers and Officials, Except Farm .....	6,124	3,749,287	1,633.4	(2)
Government officials .....	2,060	198,377	10,384.3	10
Other specified managers and officials .....	230	415,468	553.6	25
Proprietors, managers and officials, not otherwise classified, by industry .....				
Mining .....	119	30,447	3,908.4	14
Construction .....	50	113,898	439.0	26
Manufacturing .....	838	419,891	1,995.8	21
Transportation, communication and utilities .....	290	134,232	2,160.4	19
Trade .....	211	1,704,189	123.8	30
Finance, insurance and real estate .....	1,273	174,668	7,288.1	11
Personal service .....	13	123,227	105.5	31
Miscellaneous industries and services .....	1,040	434,890	2,391.4	17
Clerical, Sales and Kindred Workers .....	27	7,517,630	3.6	(5)
Bookkeepers, accountants, cashiers and ticket agents .....	19	895,965	21.2	34
Secretaries, stenographers and typists .....	6	1,056,886	5.7	35
Other clerical and kindred workers .....	2	5,564,779	.4	37
Protective Service Workers .....	545	681,534	799.7	(3)
Policemen, sheriffs and marshals .....	4	169,512	23.6	33
Soldiers, sailors, marines and coast guards ..	541	219,925	2,459.9	15
Other protective service workers .....	.....	292,097	.....	38
Total .....	31,454	20,437,113	1,539.1	..
Grand Total .....	31,454	45,166,083‡	696.4	..

\* Source: Table V.

† Source: "Occupations of Persons 14 Years Old and Over in the Labor Force, for the United States, 1940" Series P-11 Summary of Sixteenth Census, June 19, 1942. Only employed workers (except emergency work) included in this table.

‡ Female workers for the group "osteopaths, pharmacists, dentists and veterinarians" distributed according to the same proportions of male workers in these professions.

§ Total employed workers (except emergency work). Cf. footnote †, this table.

ermen and domestic and personal servants have practically no chances for eminence—that is, of course, provided they do not shift into occupations offer-

ing more opportunities for highest social recognition.

In the case of prominent contemporary Americans our knowledge is now much

more complete. Table VII contains the rates per million population, 1940, for the appearance of different vocational groups in the "Who's Who in America" list, 1938-39. This table also includes relative productivity for some industry types as derived from ratios. The professional services dominate, followed by proprietorial workers and protective service workers. Agriculture has a very unfavorable position, and clerical occupations lagged even farther behind the professional group. Domestic service workers, craftsmen, operatives and laborers contributed no prominent persons, and consequently they are absolutely inferior to any other groups in providing opportunities for national recognition.

The detailed occupational breakdown of Table VII provides data on chances for eminence by specific occupations. Subdivisions of clerical, sales and kindred workers remain as the most unfavorable vocations appearing in the list. Other clerical and kindred workers exhibited the lowest per capita position in the list, followed, in order, by trained nurses; secretaries, stenographers and typists; bookkeepers, accountants, cashiers and ticket agents; policemen, sheriffs and marshals; pharmacists; and farmers and farm managers.

Among the proprietorial group government officials stand at the top, followed by the finance group, and then by mining; miscellaneous, transportation, communication and utilities; and manufacturing proprietors, in order. The lowest proprietorial group was personal service (for example, hotel and lodging house keepers, and proprietors of laundry and dry-cleaning establishments), followed by trade proprietors. The position of the former is probably due to the low prestige of the work, while a combination of low prestige and the immense number of kinds of retail business proprietors in the country probably explains the latter.

The highest occupational positions, as would be expected from a review of the analysis of the industry groups, are among the professions, with higher education surpassing authorship-editorship by a relatively small margin. These two occupations are far ahead of all others in providing chances for social recognition, but persons engaged in such vocations as law, art, acting, architecture and medicine are ahead of all other occupations. Somewhat superior to trained nurses and pharmacists, who have fewer opportunities than the other professional groups, are osteopaths; dentists; and chemists, assayers and metallurgists. Also comparatively low in position are the bulk of the educators (elementary and secondary school superintendents, principals and teachers) and social welfare workers. Musicians and engineers stand in a position somewhat below the average for the professional group but higher than any of the non-professional classes, except government officials and financiers. The various semi-professional groups surpass many of the different specific occupations mentioned, although ranking considerably below the professional and proprietorial groups.

Protective service workers, as a group, also surpass the semi-professional workers by a small margin. But military leadership shows up fairly well in terms of the whole list. Its position is immediately above that of veterinarians, and below that of mining proprietors and engineers. It will be of considerable interest to observe the extent to which the trend of events during the war will have an effect on the number and relative importance of the military group. According to the policy of the editors of "Who's Who in America" in the past, all army officers above the rank of colonel, and corresponding officers in other services, are invited to send sketches for inclusion in the list. As the armed forces expand in

size the number of higher officers must necessarily increase and the military profession will thus tend to contribute a much higher percentage to the list as a whole. But this might not improve the chances for each military man to receive national recognition, since the standards for inclusion might be left unchanged or raised, or the proportion of general officers to all military men might change as the country is more fully converted to a war status.

The tendency for the professional occupations to offer the most chances for eminence has also been found true of Germany, and similar conditions probably hold in other countries. Agriculture offered few chances, in the case of Germany being at the bottom of the list, surpassed by persons engaged in crafts. Manufacturing and business were comparatively low in rank, but ahead of agriculture. Authorship and painting and sculpture stood out above all other occupations, with painting and sculpture leading. This is not characteristic of other countries concerning which we are able to draw conclusions. In Germany law ranked ahead of medicine, music, religion and the other intellectual and scientific professions, which offered few chances because of the large numbers of people engaged in them.<sup>8</sup>

Notwithstanding some differences between the sexes and between countries, it is apparent that there are rather uniformly superior chances for recognition for persons in the professional occupations, followed in order by government and military affairs, business, agriculture and the clerical occupations, while other occupations offer practically no chances for eminence for the average individual who remains within them.

Few data have been published on the relative contribution to a list of promi-

<sup>8</sup> Based on a comparison of the distribution of the "Wer Ists?" cases studied by Giese and the distribution of occupations in Germany. Giese, *op. cit.*, p. 20.

nent persons made by the various strata within each occupation or industry. It is known that only the superior levels of any occupation are represented among the most outstanding persons. It is illogical that a person of inferior position in an occupation should attain social recognition that has not been accorded to all persons whose positions are superior to his. In fact, only when recognition entirely rests on other things than intraoccupational status—which it only rarely does, as in the case of notorious persons—may people obtain recognition out of relationship to their wealth, authority, power to control other people or the supposed value of their contribution to society, which can never be greater than that of their superiors.

Differences in intraoccupational prestige are sharply defined and they influence social position far beyond the limits of the occupations in which they are found. A person, as representative of an occupation, can only with the greatest difficulty escape the implications of his position within the occupation. The conditions growing out of differences in status of persons of different intraoccupational strata also help to explain the small number of representatives of certain fields among lists of eminent persons, and particularly the small per capita contribution of some fields. In general those occupations that have the most rigid and the tallest hierarchy of classes, and in which the largest proportion of persons are of inferior status, are less productive of eminent persons than are the other fields, if production is considered in relation to total population. This is particularly true of mining, manufacturing, transportation and commerce. It is also more true in education than in some other fields of professional service. The most prominent exception to the principle is agriculture, but even here the proportion of laborers is large. Farmers are severely handi-

capped by reason of their place of residence and the urban point of view in the evaluation of social worth, so that the factor of class hierarchy is not needed to explain the disadvantages of the farmer. Proprietorship in agriculture is certainly not a parallel phenomenon to proprietorship in most urban occupations, because it often is not concerned with the planning and management of organizations involving large numbers of employed persons per manager and proprietor. If the data for farmers could be corrected for those items in which agriculture differs from other occupations, the importance of the structure of the intraoccupational pyramid would probably be borne out in agriculture as it is in other occupations.

#### OCCUPATIONAL PRESTIGE AND PER CAPITA PRODUCTION OF EMINENT PERSONS

There is, no doubt, a close correlation between the accepted ideas of superior social status of occupations and the prevalence of persons of various occupational groups among prominent people. An absence of representatives of the occupations of lowest prestige is particularly noteworthy, while occupations close to the top of the occupational hierarchy are relatively well represented in lists of prominent persons. The closeness of correlation, however, is not easily measured for historical personages, because of the lack of similarity of judgments of status over the entire period of history and over the entire region embraced in the studies of eminent persons made by Cattell and Castle. We know, for example, that poets had inferior status to that of statesmen, theologians and generals in past ages, even as they have less general social influence and power to-day, although the prestige of poets has varied in reference to other occupations from time to time and place to place. The same thing is true of other occupations, so that the only com-

pletely satisfactory kind of evidence on the relationship between prestige and production of eminent men must take into consideration both the production of prominent personages by each occupational group and objective information on occupational prestige for the same time and place.

Although a satisfactory standard of evidence is impossible to obtain for historically eminent persons, there is considerably more certainty for contemporary leaders. There is, for example, close agreement between the results of available data on occupational status and the ranking of per capita production of eminent men by the main classes of occupations listed in Table VII. Although there is incomplete agreement among available studies<sup>9</sup> of occupational prestige with reference to the subdivisions of the main occupational classes, the professions are at the top in prestige and per capita production of eminent personages, followed closely by business proprietors. Farmers lag behind these two, as they do in the production of leaders. Clerical, sales and kindred workers also are distinctly below professional and proprietorial workers in prestige ratings; but both farmers and clerical, sales and kindred workers surpass skilled workers, factory operatives, and personal service and unskilled workers. The similarity of occupations in prestige and productivity of leaders, therefore, is probably at least as close as that represented by a correlation coefficient of .70, which is among the higher class of coefficients for social data.

The correlation between production of leaders by an occupational group and the prestige of the workers in that occu-

<sup>9</sup> G. S. Counts, *School Review*, 33: 16-27, 1925; and W. A. Anderson, *Journal of Social Psychology*, 5: 435-466, 1934. Unpublished data from a more extensive study of occupations made by the author also support the statements in the text.

pational class is without doubt a causal one. The prestige of certain occupations increases the chances for the representatives to be included in the list of leaders, and the fact that people in certain occupations obtain recognition in such biographical directories, in the press and in other ways influences the opinions of people concerning the importance of the occupations. Even when opinions concerning the importance of occupations are not influenced by knowledge of the "Who's Who in America" occupational classification, they are conditioned by the same general sort of knowledge of leadership on an occupational basis, as is possessed by persons who suggest the names of leaders to the editors of biographical directories and by the editors themselves.

#### SUMMARY

Our knowledge of the occupational status of leaders is fairly complete in some respects.<sup>10</sup> It is known that those who are historically eminent have a different occupational distribution from that of contemporary eminent persons, and that there are sex differences in occupational distribution of notable personages. Persons in the practical sphere, statesmen, rulers and military men are proportionately more numerous among the historically great than among contemporary western peoples, while eminent men from the intellectual and artistic spheres are proportionately more numerous to-day than in past times. Eminent women in all ages have been proportionately more prominent in literature than elsewhere, in intellectual and artistic pursuits than in practical ones, and in intellectual and artistic pursuits than have eminent men. There is also considerable agreement between

the occupational distribution of contemporary eminent persons in various Western European countries, especially with regard to the main types of occupation, but there are pronounced differences between Asiatic and European countries.

The professions again lead all the large occupational classes in the relation of the "Who's Who in America" occupational population to the general employed population. Political and military affairs also show up well, as do several business proprietorial occupations, but other vocational fields reveal comparatively few opportunities for eminence. Clerical occupations are at a very serious disadvantage. Agriculture shows up only slightly better. University administration and teaching is the most favorable field for contemporary American recognition, followed by literature, religion, art and law. Other professions rank very well also, while at the other extreme personal and domestic service, skilled craftsmen, foremen, machine operatives and various unskilled labor occupations offer practically no chances for social recognition.

Only the superior classes in each occupation are represented among the most prominent people, but less important leaders include a few persons of somewhat lower intraoccupational status. So far as our knowledge goes, there is close agreement between the judgments of superiority of occupational status and the occupational distribution of prominent persons. Few of these conclusions are reliably supported and none is so certain or detailed that no other investigations need to be conducted. However, the problems are fairly well defined now, and, since the required methods of study are well known, it may be hoped that more complete evidence will soon be made available.

<sup>10</sup> See a somewhat similar condensation in Mapheus Smith, *Scientific Monthly*, 48: 560, 1939.

# THEORY AND SCIENTIFIC DEVELOPMENT

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WHAT is the role of theory in the development of science? To-day one is strongly urged to say it is to *make things work*. For we are engaged in the tasks of building guns, tanks, planes and other war-needed appliances. We are involved in the *grim* business of science. But there is a peculiar paradox in this situation: scientists give this pragmatic answer, theories are designed to make things work, with the fond hope in their hearts that some day they will be permitted to deny it; they shift emphasis from the precious and permanent aspects of their subject matter to its coarser features in order to fight a war that will bring about conditions favorable to the pursuit of a science which is *free* from utilitarian bonds.

If, therefore, I place the question of the role of theory in a larger setting, ignoring the necessary platitudes of the day, I am envisaging a post-war world. I am focusing attention upon an ideal which we are approaching, and I hope that, in perceiving its clean and lofty features on a distant horizon, we may draw the strength to conduct the grim business of science with greater vigor to-day.

There is, perhaps, another sense in which the answer I should like to give is needed in a world at war. Science has been accused of having fostered the taste for material things, of having made the murderous instruments of modern war. It has been alleged to possess no cultural value, and its emphasis upon power is said to have led to the present crisis. It is true that without theoretical science our wars would be less horrid, but it is also true that if the scientific attitude were to prevail generally, no

wars would be fought. As to the argument, however, that science is devoid of cultural value or appeal, I believe it is utterly false. Theoretical science is linked far more closely with philosophy and even the more highly developed of the social disciplines than is commonly supposed. These somewhat cryptic statements I hope to clarify. The following remarks are intended to show what it is that distinguishes *knowledge based on theory* from *empirical knowledge* based solely on fact.

First of all, let us observe theory in action. There is evidence that four thousand years ago Egyptian surveyors used in their work a bit of knowledge very much akin to the Pythagorean theorem. They called it the three-four-five rule and used it to determine the third side of a certain right triangle when the other two sides were known. The rule was gleaned from painstaking and accurate observations and was fertile in its use. The knowledge which it represents was not based on theory: It blossomed into a theory when Pythagoras, the Greek, gave his famous proof.<sup>1</sup> The problem to be analyzed here concerns the details of *what happened* when that (or any other) theory was born.

Consider another example. During the 17th and 18th centuries a useful synthesis of chemical knowledge was effected under an hypothesis which we will call the *phlogiston rule*. It developed as the result of wide and careful observations on combustion and brought forth the thesis that every combustible substance

<sup>1</sup> To be historically accurate one should concede the possibility of an anticipation of this proof by the Babylonians; but this does not matter here.

is a combination of its calx (ash) and a universal fiery principle called the phlogiston. The rule was obviously chosen to fit the visible phenomena. It was not a theory in the restricted sense in which we desire here to use that word, notwithstanding current terminology which sanctions the phrase "phlogiston theory." It was a deeper insight into matters, not solely based on observation, which, toward the end of the 18th century, caused Lavoisier to propose a *theory of combustion*, a body of propositions which can properly be called a theory in the modern sense.

To these two instances drawn from mathematics and chemistry, we add a third, illustrating the birth of a theory in modern physics. In 1885 Balmer proposed a simple formula which represented adequately and with striking precision the frequency of all spectral lines of hydrogen. His rule amounted to a beautiful synthesis of a large part of spectroscopic knowledge, but it lacked that element of metaphysical fitness, usually expressed by saying "it explains," which would have made the rule a theory. This element was added by Bohr when, in 1913, he published his work on the hydrogen atom. In what respects was our understanding deepened when this theory, or any other, came into being? I shall first review and criticize some current attitudes toward this problem.

#### ECONOMY OF THOUGHT

According to Mach, theories spring from a tendency which he terms "economy of thought." Mental effort is saved, he claims, memory is facilitated, associations between facts are more easily established, if perceptions are embedded in a rational framework. To quote him:<sup>2</sup> "The aim of natural science is to obtain connections among phenomena. Theo-

<sup>2</sup> *Die Geschichte und die Wurzel des Satzes von der Erhaltung der Arbeit*, 1871.

ries, however, are like withered leaves, which drop off after having enabled the organism of science to breathe for a time." The implication is, then, that science can live without breathing.

If this thesis is meant as a factual assertion, its truth can well be denied by reference to the observation that there is no universal urge toward economy of thought among scientists, or, indeed, anywhere among literate people; and that if there were such an urge, there would certainly be no science.

Psychologically, an effort to economize on thought is painful rather than pleasant, notwithstanding the cynical professor whose experience would seem to contravert this statement. For it is not the question whether thought is painful when it is enforced on matters of indifference to the thinker, but on matters of intense interest; for we may certainly presume that a scientist is interested in his field. If theories gratify because they conserve thought, then it is hard to see why thought-provoking utterances are generally held to be of greater value than uninspiring ones. No, the purpose served by theories is not to promote languor, but to key the mind for thought. Quite aside, however, from the psychology of the situation (which, I believe, provides a negative answer to the question "does the scientist strive for economy of thought?") suppose we were to accept an affirmative one. Science would then appear as a blight on the tranquil face of nature, the scientist as a scourge with which the devil harasses serenely thoughtless men. In fact, science, if it had ever started, would long be extinct.

But Mach's statements are hardly to be taken as positive and analyzable assertions; they aim, as do so many modern philosophical writings, to establish a point of view and not a system, to confer emphasis and not validity. It is perhaps more proper to formulate Mach's position in a more elaborate way: Economy

of thought is to be coupled with a desire to dominate an ever increasing set of facts, or sense impressions. It is obvious, one might claim, that man's natural tendency is to learn more and more about nature, for it is by controlling her that he may emerge from his primitive cave, ride the waves, cook his meat, drive his automobile and enjoy all the other comforts of civilization. Curiously enough, however, man does not like to think, or tax his memory beyond necessity, and thus he invents devices called theories which serve as receptacles for facts.

The fields of medicine, geography, botany, zoology abound with factual knowledge without theories to correlate them. I doubt very much whether in physics or mathematics, two sciences replete with theories, more facts are known than in the aforementioned disciplines. The difference is of quite another sort: theories bestow on facts a peculiar relatedness which is far from being exhausted by the quality of mere associative coherence. When a theory is shown to be wrong it is discarded and another one is put in its place: Were its purpose only to facilitate memory such a procedure would be absurd; it would be far simpler to retain the theory and learn the one fact contradicting it as an exception. Finally, even in science we distinguish rules from theories. The former are devices aiding memory, but not the latter. To summarize, then, suppose we admit that we wish to dominate nature, and wish to do this with a minimum of thought; in that case theories would not be the answer to our wishes.

Why, then, has Mach's slogan of "economy of thought" been so effective, and why is it extolled even to-day as the sinecure of all philosophical afflictions torturing the physicist? One reason is certainly to be found in the soporific nature of the doctrine. The answer it gives is so easy, and once it is accepted, economy of thought prevents all further

scrutiny which might otherwise refute it. To use another metaphor, the thesis of economy of thought has all the features of a chain reaction: as soon as it is started it produces favorable conditions for its own rapid propagation.

But let us not push this travesty too far, for it provides only a partial reason for the prevalence and the persistence of Mach's idea. It is to be acknowledged that it contains an element of truth. A theory, in order to be valid, must be *simple* in a sense to be clarified later. Of two theories, both of which are equally compatible with experimental facts, the scientist retains the one which involves the smaller number of unrelated concepts. As a case in point we recall the rivalry between the Ptolemaic geocentric and the Copernican heliocentric system of astronomy which lasted throughout the 16th and part of the 17th centuries. Copernicus' essential claim was that his hypothesis required the use of fewer independent assumptions (epicycles and deferents) than did the other. Both described the motion of the stars with equal accuracy. It was on the basis of its simplicity that the heliocentric system was finally adopted. A similar situation arose in connection with the elastic solid theory of the ether; it, too, was rejected chiefly because it became unwieldy. There is undoubtedly a significant contact between such simplicity and economy of thought, a contact which Mach would regard as the essence of the matter. Unfortunately, however, simplicity is not the only criterion for the validity of theories, nor is it the most important.

#### PREDICTION

According to one view widely held at present the function of theory is *prediction of events*; indeed, facility of prediction is often regarded as the sole, or at any rate, the most important, purpose of theoretical procedures. It will not be denied that theories permit pre-

diction in ever increasing measure, and that the practical value of a science largely resides in this circumstance. Hence whatever conclusion we shall finally reach in regard to the essential role of theory, it must account for its predictive power. But to *identify* bluntly the business of analytical investigation with prediction is not only arbitrary but misleading.

For there are, and have been, many theories which failed to predict. What Pythagoras added to the 3-4-5 rule of the Egyptians was not principally an element conducive to the discovery of further facts: it was an internal relation between facts already known, a feature far more elusive than power to predict. Lavoisier's discovery, to be sure, did lead to the important assertion, verified by experiment, that the total mass is conserved in combustion. Again, the theory of Bohr can hardly be said to have led to essential empirical results other than those already implied in Balmer's rule.

We conclude that prediction, or the acquisition of facilities for prediction, does not exhaust the meaning or the purpose of theory. The scientist need not turn prophet, nor would a successful prophet, if he did exist, be of necessity a scientist. The latter's task involves something more than mere forecasting, it involves the creation of a certain scheme in which his experience becomes peculiarly coherent, the production of an internal fitness which power to predict alone does not convey. In fact, one could name fields in modern physics where experimental facts are confusingly abundant, and where investigators would be immensely grateful for a valid theory even though it did no more than order known facts.

Theories are sometimes called beautiful or elegant. This esthetic property is ascribed to them wholly apart from their pragmatic value, indeed occasionally

when they lack pragmatic value. Every scientist has an instinctive appreciation of this quality of beauty. It is often the motive for intensive research; its achievement produces a pleasure unique in itself and not peculiar to the act of prediction, a pleasure that is present to a lesser degree whenever a problem is solved. Thus it is clear that, from a psychological point of view, the driving force in theoretical investigation is not exclusively the *fun* or the *profit* of prediction.

#### REALISM

A third point of view which was widely held half a century ago, and which is not completely extinct today, is that of realism. According to this doctrine theories portray reality. There is an objective essence, external to the mind, but waiting to be grasped and understood by the human intellect.\* There can never be an ambiguity in theory, for a theory either represents or does not represent real fact. Scientific investigation, both in its experimental and analytical aspects, is always discovery, never invention.

Toward the end of the last century realism, even in its more accentuated form of materialism, was a highly plausible philosophy. Helmholtz had shown in his brilliant lecture before the Philosophical Society in Berlin (1847) how the most general laws of physics can be derived from two simple hypotheses: (a) everything consists of point particles subject to the laws of motion; (b) all particles are subject to central forces. Clearly, then, if all empirical knowledge can be synthesized in these two general propositions, how can anyone doubt their truth? And if everything consists, in fact, of material points, how can the externality and independence of nature be denied? Explanation can not be a fictive process, it effects merely illumination of entities already given.

But alas, the two great premises of Helmholtz were shattered by science itself; they became untenable even before the century expired. Significant elements of physical "reality" were discovered which were not particles, but fields, and particles were discovered which did not interact by central forces. Explanatory procedures took on a character so abstract that their results appeared very much more like inventions than discoveries. And the hope gradually faded that it would ever be otherwise. The much discussed dualism between the wave and particle properties of light left realism completely powerless. Recognition of the fact that it is dangerous and misleading to ascribe to ultimate particles like an electron such properties as shape, size or exact position struck realism a decisive blow. There are few thinking people who still believe that an electron is an entity in the same class as this perceived desk before me.

It may be said that science has merely confirmed a fundamental criticism which semantic analysis could have made perhaps without the aid of science. For the trouble with the term realism is its superabundance of meaning coupled with its magic sound. Reference to what is *real* is expected to silence all argument. Yet there is no other word in the English language which is so ill-defined. When I speak of the reality of this desk and of the reality of the war I am using the term with two quite different connotations. It is easy to cite half a dozen others. The only person not guilty of looseness when he uses the word is the mathematician who speaks of real variables, but his meaning is philosophically uninteresting. After some thought on the matter I have come to believe that an analysis of the role of theory has a far better chance of succeeding if the word reality is banned from the discussion, unless it be clearly defined beforehand. At any rate, let us not permit the

word *real* to hypnotize us into uncritical acceptance of a point of view which modern physical science has outgrown.

#### WHAT IS PHYSICAL EXPLANATION?

The terms in which physical explanation is to be defined depend very largely on one's philosophical outlook. It is necessary, therefore, that I comment briefly on the epistemological background of the remarks to follow.<sup>3</sup> This happens to be somewhat out of adjustment with the views professed by the most prolific writers on the philosophy of science, chiefly because of the failure, on this author's part, to espouse whole-heartedly the neopositivistic doctrine. It is my belief that metaphysics can never be completely banished from exact scientific procedures, that no guarantee for permanence of a scientific theory can be gained by basing it on *facts* which, when analyzed, reveal a most bewildering array of metaphysical assumptions. Instead of closing our eyes to metaphysics and allowing it to go without control, as seems to be the current fashion, it is important that its action in modern theory be first recognized, then analyzed and harnessed for better or for worse.

Extreme positivism, culminating in the belief that all science is restricted to an analysis of sense data, is invalidated by all of theoretical physics; but nowhere is its weakness so glaringly exposed as in the recent development of quantum mechanics. Only a remnant of the positivistic doctrine has crept into the credo of modern science: it is Kant's dictum that "*Erkenntnis ohne Anschauung ist leer.*" To this maxim we shall adhere.

Admitting, then, that the scientist does not deal exclusively with sense data, such as colors, shapes, noises, smells, and pointer readings, let us at once divide his universe of discourse into two classes

<sup>3</sup> For a more extensive exposition see: H. Margenau, *Journal of Phil. of Science*, 2: 164, 1935; 6: 65, 1939; *Rev. of Mod. Physics*, 13: 176, 1941.

of things: *sense data* and *constructs*. The latter are concepts invented by rules to be mentioned later, which bear certain invariable relations to sense data, but are not themselves immediately given. Thus a certain wavelength of light is a construct associated with the (complex of) datum "blue." Other constructs are: number, integral, space, in mathematics; element, compound, valence bond, in chemistry; mass, electric field, electron, in physics. This list could be extended indefinitely; in fact, closer analysis shows that all scientifically interesting objects are constructs rather than data.

If now the role of theoretical science is to be described succinctly the following must be said: In the first place we have sense awareness. The elements of this awareness, while peculiarly vivid, spontaneous and ever-emergent, lack all attributes which allow analytic procedures amongst them, and hence do not lend themselves readily to being dominated by reason. Hence constructs are invented in such a way that (a) they stand in unique correspondence with sense data which they represent symbolically; (b) they partake of properties which make them subject to the procedures of logic and mathematics. Having translated a particular set of data into constructs, the scientist transforms these constructs, within the context of a particular theory, into others by logical and mathematical rules. He then translates the new constructs back into sense data and sees whether these, under the conditions implied by the theory, are found to be present. If so, he says that he has verified the theory (a set of constructs connected by "laws") in this particular instance; if not, the theory (or hypothesis) is discarded as not valid. A theory is said to be correct if it permits this peculiar circuit, which starts somewhere in the esthetic continuum among sense perceptions, swings into the field of constructs and finally returns to

the esthetic continuum, successfully hitting its mark; indeed, if it permits this circuit to be made without fail in all cases to which the theory has relevance.

This brief characterization will, I hope, sufficiently outline my point of view. I shall forego the opportunity of giving evidence for its correctness, chiefly because the field in which it could be tested and exemplified is extremely wide, embracing all of science. It is possible to classify the constructs used in any given science, to state the rules of correspondence between data and constructs (these are often the so-called "operational definitions") and finally to analyze the relations connecting constructs into theories. But these details must not detain us here.

#### METAPHYSICS

A construct is not a part of sense data; it is not immediately given. On the contrary, it is an entity generated by creative reason and as such not fundamentally different from the abstract notions of philosophy and theology. The difference between scientific constructs and the latter lies in this remarkable circumstance: in the selection of valid scientific constructs certain rules or requirements are being imposed which are more stringent than, or at any rate different from, those which attend the choice of non-scientific constructs. Again these rules, often dimly perceived by the philosophers of the past and regarded as invariable "categories" of thought, are not drawn from sensory experience but are strongly founded in deep-rooted conventions among scientists. An analysis of these rules, whose aggregate I shall call metaphysics because they transcend by far the domain of sensory experience, is to be the object of the present section. Metaphysics, then, as the term is here employed, does not include its traditional branch, ontology; it is simply the epistemology or, more properly, the methodology of science.

To make clear the distinctions to which attention is being called it is necessary to guard against a widespread confusion occasioned by the imperfections of language. Single words are often used to designate essentially different things. Thus in the phrase: I feel the mass of a chair when I push against it, the word mass is being used to denote a complex of sense data. The mass which appears in Newton's laws of motion is quite another entity and must not be identified logically with the former. It is to be sure, linked to it by certain correspondences (operational "definition" of mass), but it stands as a construct, a rational invention the significance of which could meaningfully be denied, were it not for its unique conformity with certain metaphysical requirements which will now be outlined.

This list of comments that follows is meant to be suggestive rather than exhaustive. Nor does it aspire to any pretense of logical demonstration which, if it could be carried out successfully, would exceed the confines of the present paper. If it is only provocative of thought, its purpose will have been achieved. My belief is that it covers the principal axioms of scientific methodology.

(a) All valid constructs must be *transitive* in the sense that it is possible to pass from one to another by logical or mathematical relations. This type of transitivity allows constructs to be connected into theories. Furthermore, there must be *some* constructs (here called pseudo-sensible) which are operationally connected via the rules of correspondence mentioned in the foregoing section, with sense data. And finally, every construct, while not necessarily connected with all other constructs, must form a transitive link with at least one pseudo-sensible construct and hence with sense experience. Thus it need not be required that every construct should

have a sensible counterpart. It is sufficient that it be transitively connected with a construct of the pseudo-sensible class.

(b) The passage from one construct to another is to be effected by the *laws of logic* and mathematics considered valid at the time. At present, these are the laws of two-valued logic, and the mathematical results based thereon. But there appears to be no reason to suppose that more general types of logic, which are now being developed, will not some day replace the familiar one. Nor is it to be argued that science must restrict its laws to the manipulation of such elementary mathematical notions as numbers and functions. Quantum theory shows, in fact, that this limitation is harmful.

(c) The correspondence once set up between data and constructs, must be *permanent*. This trivial requirement simply forbids that a symbol, such as mass or wavelength, be referred to the elements of sensory experience in an indiscriminate manner, violating the definitions.

(d) The relations among constructs are required to be *extensive*. I hasten to elucidate this unintelligible phrase by means of an example. Tradition has it that Newton saw the apple fall and in contemplation upon this phenomenon conceived the laws of motion. As an historical assertion this is certainly in error, but as an illustration it may serve. The sense data in this case are clear. By means of permanent rules of correspondence Newton arrived at the constructs mass, position, speed, acceleration. In modern parlance some of these were joined into a differential equation which Newton solved. To the solution he applied the same rules of correspondence, and these led to verified sense experiences. The circuit was completed.

But the situation would not have been satisfactory if Newton, after his excursion into the real of constructs, had been

able to predict only the position, speed, and acceleration of the apple at a single instant, namely its condition at the moment when he began reflecting. For in that case, he would have taken the same route back from constructs to data which originally led him from data to constructs. This is the situation against which we desire to guard when we insist that the constructs must be extensive. They must permit the return to sense experience on a different route than that taken originally into the realm of constructs. Moreover, they must land the investigator at a point in sense experience different from the starting point. Thus, in the present example, this criterion was satisfied because Newton was able to predict position and velocity of the apple at a different time than when his original observation was made.

So far, the illustration adverts to the barest minimum of extension to be required among constructs. But the scientist demands more. Newton would have been dissatisfied if the formation he invented for this particular apple had not been valid for other apples, or indeed, for describing the motion of the moon. It is extension of a set of constructs, or a theory, in this more general sense that forms the metaphysical requirement here under discussion.

Will the constructs of science ever be indefinitely extensive? Will there ever be one theory capable of explaining uniformly all phenomena? Many thoughtful investigations fervently affirm this theory, but their answer is given in prophetic anticipation of their fondest hope, and not in cool appraisal of present trends. For there is at present less of a unifying tendency than in other periods of the history of science, and the universal extensibility of any theory may well be doubted. I therefore favor to include in this list of metaphysical requirements, not universal extensibility, but any finite sort of extensibility at all.

(e) Perhaps the clearest and the most definite of the rules which valid theories satisfy is that of *causality*. Shorn of all technicalities, it amounts to this. One selects certain constructs having "magnitude" and regards them as defining the state of some other construct called object, or system. The former are then fed as initial or boundary conditions into some mathematical formalism, usually a set of differential equations, and a solution is obtained. This solution is valid at other times or places; the method has served to *predict* in a very general sense. Now when constructs can be selected so that this method is applicable, the theory containing them is called a causal one. To obtain a causal theory it is not sufficient to discover a law; it is necessary first of all to discover the proper constructs which are symbolic of the empirical situation and which will permit the establishment of causal laws. The admirable feature in Galileo's contribution to physics was his recognition of *acceleration* as the significant construct in the description of freely falling bodies—discovery of the law was easy after that. On the other hand, it is believed that the absence of causal laws in a large part of hydrodynamics continues not because such laws do not exist, but because the variables through which phenomena can be described causally have not been found.

It should be evident that causality is *not* a quality which adheres to sense impressions. No one who is enmeshed in this basic fallacy can see how modern science functions. It is customary to say, of course, that the seen stroke of lightning is the cause of the heard thunderclap. If this were meant in the primitive way of a relation between sense data, then it would be impossible to defend any *law* of causality in the face of Berkeley's and Hume's criticism. If, however, thunder and lightning are regarded as physical disturbances and thus

as constructs, they stand indeed in a causal relation via the laws of physics. What significance, then, is to be ascribed to the statement: we live in a causal world? Only this: our experiences are such that they can be represented by constructs subject to the methodological requirement of causality.

It is often asserted that causality no longer holds in quantum theory. This, however, must not be taken too seriously. The facts are these. In classical physics, the variables leading to causal description are, principally, the position and the momentum of a body. These fail to produce a causal representation for bodies on an atomic scale of magnitude. If, however, the state of the body is re-defined in terms of other constructs the scheme becomes causal again. What worries many writers is that position and momentum still are not causally determined. But this is hardly more surprising than the fact that Newton's laws are non-causal with respect to the color of the object they describe.

(f) The list of metaphysical requirements would be incomplete without inclusion of one final item, *simplicity*. This does not mean that constructs to be simple, must partake of immediately intuited properties designed for visualization: explanation need not be in terms of mechanical or any other kind of models. But it does mean that the number of independently defined constructs appearing in any theory be held to a minimum. Thus, for example, the electromagnetic theory of light is simpler than the elastic ether theory, although the latter is far more readily visualized than the former. The fault of the ether hypothesis is that it becomes top-heavy with artificial assumptions when it is made to account for the speed of light and other matters. It violates the requirement of simplicity.

This postulate is vague indeed. Its vagueness, however, does not impair its use; for it is invoked only when two rival

theories compete for acceptance. When that happens there is usually some dissension among scientists, but history shows that it subsides and that the theory with the smaller number of independent constructs invariably prevails—provided, of course, that it is equally well confirmed.

The requirement of confirmation has not been added to this list, for it is so basic in the scientist's methodology that it needs no special mention. It inheres in the possibility of performing the circuit of explanation sketched in the foregoing section and is equivalent to it. A scientific construct, or a set of constructs joined into a theory, is said to be *valid* if, aside from being a link in confirmed circuits of explanation, it satisfies requirements outlined above.

#### THE PHYSICAL UNIVERSE

But what, then, is the physical universe? To answer this question it is quite unnecessary to become involved in perplexing arguments concerning the external reality of things. For this latter quality—if it be called a quality—we certainly do not observe it nor do we find a valid scientific construct which corresponds to it. Let us look at the situation carefully. Why do we say that certain external objects are part of the physical universe whereas a seen ghost is not? The basis in individual sense data may be equally vivid, strong and convincing; hallucinations are known to be often more vivid than bona fide perceptions. The reason for the distinction lies only in the fact that the external objects, as constructs, embed themselves in a peculiar nexus with other constructs, satisfying the metaphysical requirements for valid constructs in a simple, sometimes rudimentary way, whereas the apparition does not. Things are said to be objective, external to us, or independent of our minds, when they partake of the relatedness and internal organization

which confers validity on constructs. The atom, the electron form part of the physical universe in this sense, and in no other. But their "reality," if the term must be used, is therefore just as unquestionable as that of more familiar constructs.

Some will insist that sense data, also, belong to the physical universe. There is, I suppose, no harm in admitting them if only the dichotomy existing between them and the other elements is not overlooked. To wipe out the distinction, however, and to treat constructs as though they were sense data, leads to all the confusion and infelicity of expression, all the empty verbal argumentation which has often marred the philosophy of science.

According to this view, the physical universe is changing. It is a dynamic universe, one that is not being discovered as a static entity, but constructed as a thing of growing complexity and, we hope, perfection. Understanding is a matter of approach to an ideal, not a grasping of a fact already there. I believe that only this dynamic view conveys the perspective of modern science; the older realistic doctrine imprisons its spirit and obstructs its creative force.

If building a universe in which man's thought and actions play a dominant role is deemed anthropomorphic, then the present conception is anthropomorphic. The alternative, a universe apart from man's thought and actions entrains

the most embarrassing philosophical difficulties, and is without fertility in ethics and the social sciences. But here we are perhaps approaching issues which may be judged to be beyond the competence of present scientific methodology. Opponents of the exact sciences have spared none of their eloquence in disparaging the ephemeral nature of science. As an example, a most entertaining article by Stephen Leacock<sup>4</sup> may be cited. His criticism would not fail to be appreciated if the point of view of naive realism were still common among scientists; it would then be serious. As they stand, his arguments add further evidence to the constructional, dynamic interpretation of the universe. Even the old realistic world was conceded to change its properties in time. Why should it not change its contents when new, valid theories are developed?

The foregoing discussion emphasizes the inseparability of fundamental theory from all scientific pursuits. The emphasis is perhaps untimely, since the practice in authoritarian countries, followed by a war-born shift of attitude even in the democracies, has added glamor to one-sided, practical scientific endeavors. Let no humanist fear, however, that this is a permanent change. For all science would stagnate without the benefit of theoretical and philosophical stimulation.

<sup>4</sup> Stephen Leacock, *Atlantic Monthly*, May, 1942.

## SOME CTENOPHORE FISH-CATCHERS

By Dr. E. W. GUDGER

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IN a number of articles I have brought together all the facts and figures I could find relating to the fish-catching and fish-eating habits of the Coelenterate, or hollow-bodied, water-dwellers. These animals, of which probably the best known are the fresh-water hydra and the marine jellyfishes, sea anemones and coral polyps (*not* "insects"), have a pronounced radial or starfish-like symmetry, the organs radiating out from a common center. Most, if not all, have the mouth surrounded by tentacles and both body and tentacles are abundantly supplied with poisonous nettle cells. With the nettle cells fishes are paralyzed and with the tentacles are brought to the mouth, whence they are carried into the body cavity and there digested.

The Ctenophores, or comb-bearers, as the figures show are transparent gelatinous water-dwellers, generally spherical or lobed, provided with a central cavity. They outwardly resemble the Coelenterates, with which they were formerly grouped. But they have only two tentacles instead of many and are entirely devoid of the poisonous stinging cells so characteristic of the Coelenterates. The tentacles are solid and each usually bears a row of short pinnae (Fig. 1). Both tentacles and pinnae are covered with cells called "colloblasts," or glue cells, which secrete little globules of gluey or adhesive matter. These cells with their secretion stick to any small objects which touch them, and hence with this secretion the Ctenophores catch their prey in very much the same fashion as the Coelenterates do with their stinging cells. The comb-bearers have the swimming organs arranged in four radially placed comb-like plates.

These characters and others not so apparent have led to the taking of these animals out of the coelenterate group and to the placing of them in a great zoological group or phylum of their own—the Ctenophora, or comb-bearers.

And now, having cleared up these points, let us turn to the, to-us, more interesting and important matters of their food and feeding habits.

The Ctenophores are not well known to the general run of zoologists and their food and feeding habits are almost unknown even to specialists in this group. Thus the author of the section on these animals in Volume I of the "Cambridge Natural History" (1909) makes no reference whatever to their food and feeding habits. While an American authority merely says of the Ctenophores that, "Their food consists of crustaceans, fishes and other small animals, often including their own kind." However, Alfred G. Mayor, in his monograph on the Western North Atlantic Ctenophora, explicitly states that "... their food consists largely of young fishes which they engulf in great numbers, seizing their

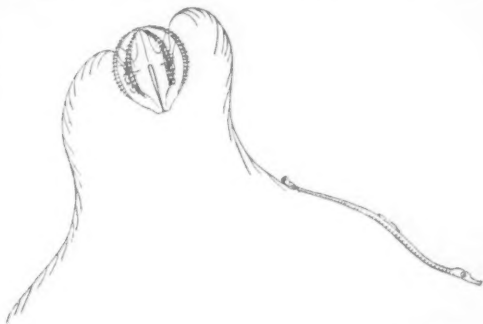


FIG. 1. CTENOPHORE FISH-CATCHER  
THE COMB-JELLY 10 MILLIMETERS LONG IN BODY,  
HAS LASSOED A 25-MILLIMETER BABY PIPEFISH.\*

\* Each of the figures is after Lebour.

prey by means of their peculiar "Greifzellen" [pinnae]." Neither writer gives any references to help us along. It may be added that, when captured, Ctenophores are generally empty. However, this must be attributed to rapid digestion rather than to a starvation diet.

These small carnivorous marine animals must feed on the minute forms, the plankton, floating or swimming at the surface of the sea. It seems impossible that they, being small, weak and apparently helpless, can catch and devour such relatively strong and active swimmers as even small fishes. Information along this line is desirable and fortunately is forthcoming.

#### *Mertensia ovum*, A FISH-EATER

When I wrote Dr. Henry B. Bigelow, Director of the Oceanographic Institute at Woods Hole, asking for information and references as to the fish-catching habits of the comb-bearers, he answered that the only one of which he had a record is that one bearing the formidable name above. It has no common name, unless we use the translation—Merten's egg-shaped comb-bearer. In 1780 this form was discovered by Fabricius and by him named *Mertensia* in honor of Professor F. C. Mertens of Bremen, a marine botanist (if one may so designate a student of seaweeds). Nothing unusual seems to have been known about this comb-bearer until in 1909 when Dr. Bigelow,<sup>1</sup> on examining some specimens taken off the Labrador coast, found that one was a fish-eater.

Of his specimen, Dr. Bigelow wrote that, "The voracity of this form is well illustrated by the fact that one individual [about 10 millimeters in height] had entirely engulfed a young sculpin no less than 21 millimeters long, the victim being doubled up so as to fit into the digestive cavity of its captor."

<sup>1</sup> Henry B. Bigelow. Coelenterates from Labrador and Newfoundland. *Proc. U. S. Nat. Mus.*, 37: 317, 1909.

Other than the above, all records come from Dr. Marie Lebour and from the Plymouth (England) Laboratory. In 1922, she made the first of her records and (so far as I have found) the second known personal record that Ctenophores catch and eat fishes. It seems well to quote her very words. In writing of the food of plankton organisms, she refers to that of one ctenophore kept under observation in an aquarium with a plunger for aeration of the water without changing it.

#### *Pleurobrachia pileus*, A FISH-CATCHER

This animal has no common name but a translation of its scientific name quite accurately describes it. *Pileus* means a cap, in allusion to the shape of the body of the animal, while *Pleurobrachia* apparently means having side branches, in allusion to the frilled chin strings of the cap, the tentacles with their many pinnae—as shown in the figure. Of this animal, Dr. Lebour<sup>2</sup> writes (1922, p. 665) that: "In other years when records were not kept, *Pleurobrachia* was often seen to be eating young fishes, although only one is recorded here [with a young *Labrus* in it]." Her records published in 1923<sup>3</sup> are much fuller and hence of greater value:

*Pleurobrachia* is known to eat young fishes amongst the large variety of food which it takes. Several ranging, from 3 to 10 mm long, were kept alive in the plunger jars from June to August, 1922.

These ate . . . [among other organisms] pipefishes (*Syngnathus*, about 25 mm. or one inch long). In one case a *Pleurobrachia*, about 10 mm. long [body only] caught a pipefish, about 25 mm. long (Fig. 1). After playing with it for half an hour the fish escaped, carrying most of the tentacle with it. The heads of the pipefishes eaten are usually ejected. A *Pleurobrachia* about 4 mm. long caught and partly digested a goby over 10 mm. long, which it could not get entirely into its mouth.

<sup>2</sup> Marie Lebour. The food of plankton organisms. *Jour. Marine Biol. Assoc., U. K., Plymouth*, 12: 664-7, 1922.

<sup>3</sup> Marie Lebour. The food of plankton organisms. II. *Jour. Marine Biol. Assoc. U. K.*, 13: 85-87, 1923.

When strong and well the Pleurobrachia has its tentacles with their pinnae fully outstretched and catches the food as it passes by, immediate reaction taking place at the touch of the prey, which is [held by the glue cells] entangled in the contracted tentacle and conveyed to the mouth and stomach.

Dr. Lebour examined tow-net material collected in the eastern part of the English Channel in January, 1923. Pleurobrachias in it were very large—about 18 millimeters in diameter. Nearly all of these had eaten fish eggs or young fishes, some of them having the mouth and stomach “enormously extended, the aperture being nearly half the diameter of the body,” as is shown in the subjoined Fig. 2. Here follow some detailed counts, segregated in lots according as the material came in.

Of large Pleurobrachias (18-20 millimeters in diameter), Lot I contained eggs and young fishes as follows—two contained one herring each; one, two herring; and one several herring; and three had swallowed plaice eggs. Of Lot II, three contained one herring each; one, had two; four had three; two had four; one had five; three were crammed with six herring each; and one with two larval plaice (much larger than the herring). Of Lot III, one contained several larval herring and three had eaten plaice eggs. Of Lot IV, Dr. Lebour notes “Many Pleurobrachia containing herring larvae.” Tow-net records for June, July and August, show various young fishes in smaller numbers contained in specimens of this Ctenophore.

Now follows Dr. Lebour's<sup>4</sup> interesting account (1925) of her observations of fish-catching by the Ctenophore lacking the long tentacles so skillfully used by Pleurobrachia.

#### *Bolina infundibulum* CATCHES AND EATS YOUNG ANGLERS

The dictionary tells us that *Bolina* is a made-up New Latin word but gives us

<sup>4</sup> Marie Lebour. Young Anglers in Captivity and some of their Enemies. *Jour. Marine Biol. Assoc. V. K.*, 13: 728, 1925.

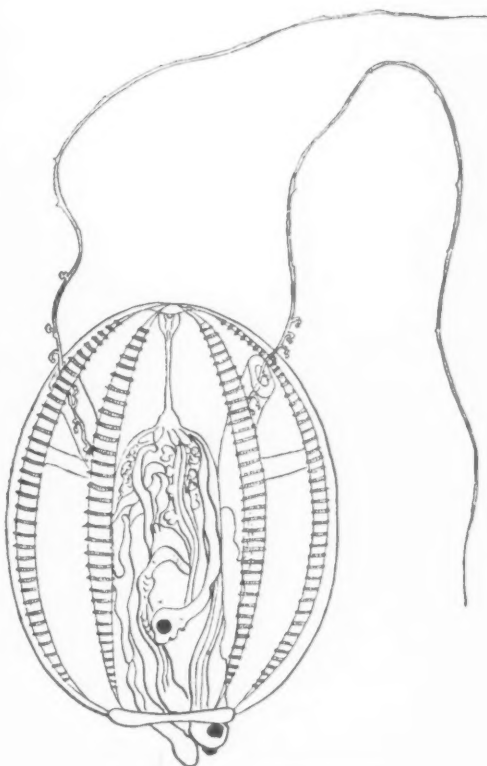


FIG. 2. A CTENOPHORE FILLED WITH YOUNG HERRING. THIS SPECIES FEEDS EXTENSIVELY ON LARVAL HERRING.

no derivation. Infundibulum refers to the funnel-shaped mouth. Hence this Ctenophore is *Bolina* with the funnel-shaped mouth—into which it takes little fishes. And here is how it does it.

These lobate ctenophores appeared suddenly in the jar early in the spring, having apparently been introduced as eggs when very fine plankton was put in. They had been feeding freely on copepods and it was thought that the Anglers would be safe beside them. This was, however, not the case, for the *Bolina* caught and ate many of the little fishes. The method adopted was interesting. The ctenophore would catch an actively moving fish with its tentacles, which although short are very powerful, and as the fish struggled the lobes would close on it, shutting it in, when it was quickly taken by the mouth, from there it reached the stomach and was digested [Fig. 5 a-d; my Fig. 3 a-d]. *Bolina* from 4 mm. to 30 mm. long would catch fishes in this way, the smallest taking one longer than itself, the largest sometimes taking two at a time or eating one after another. *Bolina* is thus seen to be extremely voracious and evidently able to

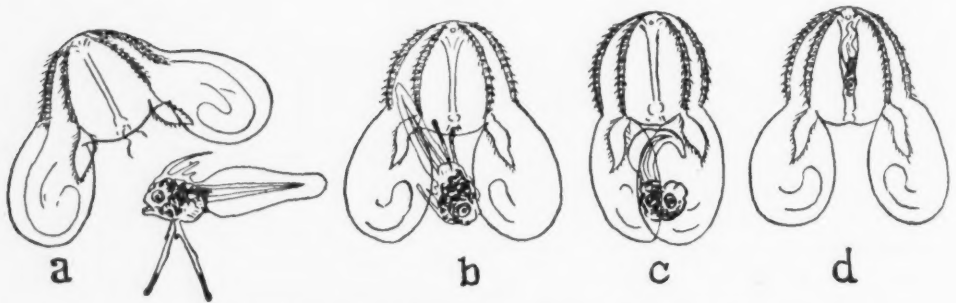


FIG. 3. THE COMB-BEARER CAPTURES A YOUNG ANGLER  
 (a) THE LITTLE ANGLER WALKS INTO DANGER; (b) HE IS BEING FIRMLY GRASPED BY THE TENTACLES;  
 (c) INGESTION IS GOING ON; (d) MAY BE LABELLED "DIGESTED."

tackle larger food than any previous knowledge of its feeding habits has hitherto shown. Altogether it accounted for the death of many of the Anglers, which would quickly run out of the way and hence required a good deal of catching. Those of all ages, from newly hatched specimens to those of the tenth day, were taken and always from near the surface or center of the jar never at the bottom.

By now the reader is asking, "Can these animals, which are so small and helpless, do so much damage to a crop of young fishes as to justify their being designated as their 'enemies'?" On this point we have the following general statement from Mayor<sup>5</sup> (1912): "In cold northern waters, where Ctenophores occur in vast swarms, they constitute a serious menace to the cod fisheries by devouring the pelagic eggs and young fish." Then when one reads in Dr. Lebour's scanty records that nine had

<sup>5</sup> Alfred G. Mayor. *The Ctenophores of the Atlantic Coast of North America*. Carnegie Institution of Washington. (Ctenophores feeding on fishes, pp. 6 and 7).

eaten fish eggs; that several contained three, four and five fishes each, and that three had gorged themselves with six herring each; that several had swallowed fishes larger than themselves; and that in all 21 Ctenophores contained a total of 66 baby fishes—one must surely consider them as "enemies." This is confirmed when one learns that Ctenophores go about in great shoals, sometimes acres in extent—all seeking food, young fishes among other things.

To recapitulate: The few samples taken at random from tow-nettings show that these hungry little animals have captured considerable numbers of baby fishes. Multiply these few individuals by the countless numbers contained in an acre-sized shoal. Then from this astronomical number one can get an idea of the heavy toll of young fishes taken by these voracious Ctenophores. Surely they are to be set down as "Enemies of Fishes."

## AN AMERICAN PIONEER IN SCIENCE, DR. WILLIAM CHARLES WELLS, 1757-1817

By Dr. CHARLES A. KOFOID

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In reality the only claim America has upon the fame of Dr. William Charles Wells (1757-1817), a pioneer in physics, meteorology, ophthalmology, epidemiology, and anticipator of Darwin, is his birth at Charlestown, South Carolina. He never forgot his Scottish ancestry and this allegiance was reinforced by his education at the Grammar School at Dumfries, and his medical degree from Edinburgh. Furthermore his whole intellectual life was later centered in the Royal Society of London.

He never mentions his native land, never sought the acquaintance of Benjamin Franklin, and his recollections of Charlestown were embittered by memories of court-martials of fellow citizens in the political turmoil of the rising tide of the Revolution. As a refugee loyalist at the close of the War of Independence he had sought asylum in Florida where, with the aid of a "Printer's Grammar" and a negro slave, he set up and printed the first newspaper published in that state. His brief career in Charlestown as a printer, publisher, and merchant culminated in the settlement of the family estate which left him saddled with a debt of honor of £600 which it took him many years to pay off. His lingering bitterness against his American background emerges in his anonymous tirade in the *London Advertiser* against the fitness of Henry Laurens, chairman of the Constitutional Convention, to represent the American Republic at the Court of St. James.

There was, however, one bright spot in this dismal background. It was the friendship of Dr. Alexander Garden of Charlestown, his guide and counsellor in

youth and his medical preceptor. Dr. Garden was the leading scientist of the Carolinas, a correspondent and member of the Royal Society, and a botanist of note whose name is enshrined in the fragrant *Gardenia*. In the atmosphere of this friendship Wells' scientific and medical interests found a congenial environment and he records his appreciation of its lasting influence upon his career.

It was this American environment, however, which gave Wells an insight into the contrasts between the white and negro races and revealed to his analytical mind their differential survival to the decimating diseases of consumption and ague, a contrast which was of assistance to him in formulating his theory of natural selection.

Like many American youths of his day he went to the University of Edinburgh where he attended medical lectures, passed the examinations, but wrote his thesis in Leyden in 1779 on *De Frigore*, a forecast of his lifelong interest in the formation of dew. After attendance at St. Bartholomew's Hospital in London he returned to Edinburgh for his degree in 1780.

Scientific ideas vary greatly in their significance. Some concern only a minor supporting factor in a larger edifice, such as the meaning of vestigial organs seen in the gill slits in the neck of the mammalian embryo but never directly used in respiration. Others form the foundation of a growing and changing superstructure whence radiate influences which stimulate new points of view in widely different fields of human thought and activity. Such an idea is

that of the origin of species by natural selection, often called Darwinism, or less accurately evolution, or to limit it to the living world, organic evolution.

Charles Darwin, however, did not use the word evolution in his "Origin of Species," but his masterpiece attracted world-wide attention to the process to which the writings of Herbert Spencer and Thomas H. Huxley later attached the word evolution and thus gave to it a lasting place in popular parlance.

Wherever some seemingly new idea is broached, given popularity, and comes to be associated with the proposer's name, critics appear who find that the theme after all is not so new, that others have expressed the same bright idea. They thus proceed to rub off the sheen from the supposedly pristine contribution. Exactly this happened to Charles Darwin's concept (1859) of the origin of species by natural selection. By the time the fourth edition (1866) of his masterpiece appeared his expanding correspondence had brought to him evidence that he had been explicitly anticipated by at least two naturalists of British affiliation. He generously gave credit to his anticipators in his historical introduction to that edition. These anticipators were Matthews in his "Naval Timber" and Dr. W. C. Wells in his "Account of a White Female part of whose skin resembles that of a Negro."

One would hardly expect the outline of a major biological theory in a dry and technical treatise urging an adequate and continuous supply of building material for the bulwarks of the "Royal Oaks" of Britain's navy. Yet here it is in Matthews work interlarded in a plea for more oaks, not of the ordinary quality but of an increasingly better one. This is to be accomplished by a survey of all of the known varieties of oaks, the selection of the finest and their interbreeding, the planting of acorns from these paragons which would supposedly transmit to their progeny the qualities

selected. Then in due time the British forests of oak would be transformed into groves of new and better oaks.

The second anticipator of this discovery of change in the hereditary patterns of living things by natural selection both deserved and received Darwin's fullest recognition. He cites Wells' paper on "An Account of a White Female part of whose skin resembles that of a Negro" read before the Royal Society of London in 1813 but not published till 1818 after the author's death. He acknowledges that in this paper Wells distinctly recognizes the principle of natural selection and that this was the first published statement of that principle, but states that Wells applied it only to the races of men and to certain characters alone. In these restrictions Darwin overlooked the fact that Wells noted that "amongst men as well as among animals varieties of a greater or less magnitude are constantly occurring" and that he also specifically cited selection constantly occurring in sheep. Wells also compared natural selection in human characteristics with man's artificial selection among variations of his domesticated animals, noted the survival value of the variations on which selection acted, the swamping out of these characters by interbreeding, the non-inheritance of some characters (since he knew nothing of Mendelism and recessive characters) and the effect of isolation in conserving the characters selected. By a clean-cut process of ratiocination he resolves this instance of a pinto female into a full-blown theory of variation, selection, descent with modification, and the origin of new races of men. He draws upon his knowledge of the reaction of human races to disease as an instance of the operation of selection. It is of interest on this point to recall that although Darwin had studied medicine at Edinburgh he never mentions disease as a selective agency in his "Origin of Species" and only casually notes it in his "Descent

of Man." Wells, on the other hand, utilizes it as a potent agency in the evolutionary process.

The wish to learn more of the character and other writings of this anticipator of Darwin led me in a month of leisure in November 1936 to consult the great library of the British Museum and the manuscripts of the Royal Society. In the nearby library of the College of Physicians and Surgeons was found his contributions to the little known "Transactions of a Society for the Improvement of Medicine and Chirurgy," all but still-born before its time, which bear further witness to the intellectual keenness of Wells' mind. Before the days of Pasteur he maintained that erysipelas was contagious and long before the word epidemiology was coined he pioneered therein with a discussion of the seeming opposition in occurrence between consumption and ague.

It was not, however, in his chosen profession that Wells exhibited his prowess, for he seems to have been but a mediocre practitioner, barely eking out a meager living in spite of his affiliation with one of the greatest of London's hospitals. He was, however, constructively interested in the standing of his profession as shown by his fight for the rights of graduates of Scottish Universities as against the entrenched privileges of those of Oxford and Cambridge who then constituted the membership of the College of Physicians and Surgeons. A court decision had equalized these but the privileged group had as yet made no move to put the liberal policy in action. When later the College of Physicians and Surgeons offered membership to him he declined it because of this illiberal policy.

His scientific fame rests on three contributions in widely separated fields, namely his anticipation of the evolutionary doctrine of natural selection, his penetrating discussion of the perennial problem of single vision with two eyes,

and the logical explanation of the recurrent commonplace of the deposition of dew on clear nights.

The first of these touches upon a theme of greatest importance, namely, the factors in organic evolution. It also anticipates in its statement of the argument, Darwin's own presentation of the origin of species by natural selection. This, however, was the least elaborated of the three major contributions and remained unpublished until after his death and practically unnoticed thereafter, until Darwin gave it posthumous fame in the historical introduction to the fourth edition of the "Origin of Species." At most Wells' reference to the selective process is only a casual comment on an interesting abnormality occasioned by his contact with a case of a White Pinto, that is, a person with contrasted regions of white and black skin. This led to his disquisition on the causes of differences in color and form between the white and negro races of men. This paper was presented by Wells before the Royal Society of London on the first and eighth of April, 1813. In the manuscript book of minutes of the Royal Society the secretary gives an excellent résumé of the paper, possibly furnished by Wells, but no comment appears in the record for this division between two sessions or of any discussion aroused by its reading. The paper was published after his death but excited no comment or criticism at that time or later.

The manuscript of this paper was found upon search among the uncatalogued papers of the Royal Society by whose courtesy a photostat was made of it. A comparison of this with Wells' signature in the records of the Royal Society supports the conjecture that the manuscript is in Wells' own handwriting. A comparison of this manuscript with the text of the article in his collected works, edited presumably by Dr. Patrick, reveals no evidence of modifica-

tion due to contemporary discussion or general criticism. It was only after the doctrine of Special Creation had been challenged that Wells' ideas acquired significance.

A search for evidences that he had been directly influenced by contemporary French thought on evolution was fruitless, there being no suggestion that he had made contacts with either Buffon or Lamarek or that he even knew of their writings. A possible indirect relation exists through his friend David Hume, who visited France and writes of his pleasure in his conversations with the brilliant Buffon. All of this goes to show that Wells himself was unaware in his time of the far-reaching turmoil of thought which would one day be set in motion by his casual ideas on natural selection, under the impetus of Charles Darwin.

Wells' fame rests, however, not so much upon his anticipations of Darwin as upon his "Essay on Dew." His interest in temperature and the far-reaching effects of its changes upon nature and man was further stimulated by one of his patients, a retired merchant from India, who told him of the commercial production of ice in Calcutta by the primitive method of exposing water on clear nights in shallow pans of porous earthenware on wet straw in the unshaded moonlight. The rapid radiation of heat from the pan and the straw, under these conditions, sufficed to form ice in the pan. Wells was wont to leave the perpetual haze of London and to experiment on the formation of dew in the garden of his merchant friend in the moonlit suburbs. These experiments led

in time to his "Essay on Dew" which won for him the Rumford gold and silver medals and membership in the Royal Society of London, than which there is no higher scientific honor.

Many other physicists and meteorologists had anticipated Wells in experimental analyses of various factors in the formation of dew, but it remained for him on the basis of his own experiments to determine and to formulate a complete theory. So complete and so logical was this presentation that John Stuart Mill in his "System of Logic" quotes this essay as a perfect example of logical induction. He concludes that "The accumulated proof of which the 'Theory of Dew' has been found susceptible is a striking instance of the fullness of assurance which the inductive evidence of laws of causation may attain, in cases in which the invariable sequence is by no means obvious to the superficial view." Herschel selects Wells' theory of dew as "one of the most beautiful specimens we can call to mind of inductive experimental enquiry lying within a moderate compass."

Science advances step by step of verifiable discoveries of basic truths and by the incorporation of these in hypotheses the reliability of which can be tested by experiment. The inductive method of scientific discovery which Lord Bacon advocated but never used was logically and expertly applied by Wells. His work is a milestone in the history of science. He had one of those rare analytical minds which discover and formulate from the temporary and commonplace the abiding and universal laws of nature.

## BOOKS ON SCIENCE

### CIVILIZATION AND TEETH<sup>1</sup>

"Your Teeth: Their Past, Present and Probable Future" is a perfect résumé of dental history and is the only book I have read, scientific or otherwise, with which I agree in every respect. From the number of references cited, it must have taken extensive reading and study, as well as time, to abstract and compile all the data accumulated. It is a book which should be read not only by every dentist, but by every dental student as well, for the facts presented will help the student at the beginning of his dental career from being misled by the "cure-alls" for dental troubles which are flooding the dental offices to-day. However, I doubt if many lay readers will continue beyond the first or second chapters, as few people to-day are interested in preventive dentistry or medicine. I make this observation from my own practice, where the large majority of my patients refuse to listen or to do those things which will prevent additional cavities. While this book is one of facts, it does not give the dental profession the answer to the question, "What can I do to preserve beautiful teeth?" and I am still in a quandary as to what I should do with my patients to prevent dental decay.

There is no doubt that civilization is the cause of dental diseases. The process of chewing is a lost art, for most of our chewing has been done at Battle Creek, Michigan, and other centers where prepared foods are made. At the table, the little child of three or four is told to keep his lips shut and not make any noise in the process of eating, which is a physical impossibility with real chewing. And after eating this mush and paste that

foods have become, this little child must not take his tongue and clean the gums and tissues to rid the mouth immediately of large food particles. Instead, the debris is allowed to remain there, for it is not nice and not good manners to hear the noises of saliva going around and between the teeth. Thus, the interproximal spaces and gingival margins are crammed with this food material, until such time as the child is old enough to use a toothbrush. And, then, what is the child given? A brush which is stiff enough to take the surface from any furniture, with which he is taught to scrub the buccal and labial surfaces of the teeth with some kind of tooth powder or paste, doing absolutely nothing for the interproximal spaces, where most of the trouble begins. It is true that a clean tooth never decays, and to clean the buccal and labial surfaces of the teeth, which usually never decay anyway, is about all that is accomplished by the average person.

The result of this modern culture is that the chemistry and bacteriology of the retained foods cause the teeth to disintegrate, with the resultant pyorrhea and abscesses, which have impaired the health of many individuals. This is described fully in the second and third chapters.

By reason of modern foods, loss of teeth and impaired function from generation to generation, we come down to the present day of dental deformities and the lack of physical development of the individual in a large number of cases, when we study and compare the teeth of those peoples who live primitively and the transition in animals from their native land to the domestic home. These data are clearly proved by the facts presented in chapters seven and eight.

<sup>1</sup> *Your Teeth: Their Past, Present and Probable Future*. Peter J. Brekhuis. Illustrated. xvii+255 pp. \$2.50. 1941. The University of Minnesota Press.

The wonderful strides made in dentistry have not kept pace with the crying need for more dentists, and I believe it is an impossibility at the present time to have sufficient dentistry in every town and village to care for all the children and adults who need attention. All the congresses, surveys and recommendations to state and federal agencies will help, but they will never correct or prevent the most widespread disease of civilization, dental caries. It is true that we have investigators searching for the cause of our tooth troubles with the aid of the microscope, modern chemistry and biochemistry, but I agree with the author that the end results of these investigations will get us nowhere until we change our mode of living, going back to the "good old days," which are gone, never to return. Just about the time, in generations to come, that a "cure-all" for dental ills will have been discovered, the human race will probably be devoid of teeth, and then, of course, the "cure-all" will be unnecessary.

One subject on which the author has not touched is the clear evidence that under normal conditions the use of the toothbrush is not indicated and that people should not need to clean their teeth. The clear mucine which covers the teeth at all times is the protective coating against acids taken into the mouth in the form of foods, such as the acid of lemon. The enamel of a tooth, perfectly clean and free of mucine, immersed in lemon juice will be etched much the same as hydrofluoric acid will etch glass, and if the mucine of modern man could be changed to the qualities of primitive mucine, it would not collect these liquid foods and hold them against the teeth with the consequent decay. With me, to-day the question is, "Which does the greater damage, 'depraved saliva' or scrubbing with a toothbrush?" I recommend to my patients the use of the softest toothbrush available, so that they will be

able to mash the brush between the interproximal spaces without injuring the gums, to remove this film of mucine with its contained food particles. In a very few cases, this "depraved saliva" or film has been changed by diet to one which will not collect these food particles. Not a complicated diet, but just natural foods. No artificial sugar, but the natural sugars of ripe fruits; no white flour; no pies, cakes, nor candy; just natural foods—fruits, vegetables, meat, milk, eggs, butter, etc., properly cooked.

The past is prologue, the present is calamity, and the future will take care of itself.

R. K. THOMPSON

#### A PHILOSOPHY OF EDUCATION<sup>1</sup>

THE idea underlying this volume in the philosophy of education is a very excellent one. Indeed it is unique among books in this field. Even though the execution of the book does not quite live up to the excellence of its conception, its unique approach to the philosophy of education amply justifies its publication and recommends its reading and study.

The way in which the book is conceived and organized is very reminiscent of the role President Hutchins assigned to philosophy in his lectures published as "The Higher Learning in America." There he calls attention to a certain atomism in our education. He finds that students study a great variety of discrete courses, but nowhere is provision made for bringing them into any integrated relation to each other. This should be the role of philosophy. Philosophy should not be only one more atom in the curriculum; on the contrary, it should be even more an integrating matrix for them all. Indeed, it should be the very queen of the arts and sciences.

President Hutchins' critics have borne down so heavily upon *his particular*

<sup>1</sup> *An American Philosophy of Education*. J. C. Knode, editor. viii + 553 pp. \$3.25. 1942. D. Van Nostrand and Company.

philosophy that the importance he has attached to the unique role of any philosophy has been unfortunately much neglected. This function of philosophy, far from being overlooked in the volume under consideration, is the very principle of its organization. To the editor and his collaborators it appears that a satisfactory philosophy of education is not an isolated nor narrow set of educational theories concerning the methods and curricula of the school. Rather is it a point of view which draws its strength from an intimate acquaintance with the broad field of culture.

In the opening chapters of the book the young teacher's attention is first directed to the background materials in science, history, philosophy, literature and fine arts which he will need as a basis for his philosophy of education. The editor's collaborators have contributed chapters in these fields which are admirable for the way in which they have mobilized the most important items in the economy of space allotted. The editor himself has contributed the philosophical background. But most significant he has written the all-important chapter, "Toward Synthesis."

As already said, this is an excellent pattern for a book on the philosophy of education. But it has limitations—of execution if not of design. In the first place it lacks chapters on parts of the cultural background which are eminently necessary, such as chapters on politics and economics. This is not to say that these topics are altogether slighted, but they are not given coordinate status, as they should be, with such

chapters as those on biology, psychology and sociology. In the second place the book seems to have overdone its chief merit; it appears to be overweighted in the direction of cultural backgrounds for a philosophy of education. There is such an emphasis on cultural point of view that anxiety may seriously be entertained whether the "young teacher," to whom the introduction is addressed, will readily see its application or significance for the practical every-day concerns of method, curriculum and administration. Perhaps this is the area to which classroom instruction is to address itself. In other words, in the last place, there is a larger job of "synthesis" to be done than just one chapter allows for. The editor has striven valiantly to bring the materials of a dozen or more chapters into focus but the materials with which he was wrestling were so vast that he might well have allowed himself at least two or three more chapters in which to complete his task.

The very least that can be said for the book is that it is a definite and worthy contribution to the teaching of philosophy of education at its weakest point in this country, the cultural background of the prospective teacher. It is a cultural orientation and summary for him if nothing else. As such it should be at least a companion or supplementary volume for almost any course in the philosophy of education that one could mention. At best, particularly with good teaching, the book can aspire to the regal role prescribed by President Hutchins for philosophy.

JOHN S. BRUBACHER



DR. ARTHUR B. LAMB

## THE PROGRESS OF SCIENCE

DR. ARTHUR B. LAMB, RECIPIENT OF THE  
WILLIAM H. NICHOLS MEDAL<sup>1</sup>

IN an age of specialization which is constantly becoming deeper and narrower especially in the sciences, Arthur Becket Lamb is an inspiring exception. He stands as solid proof that broad training and experience are not incompatible with the highest success in a narrower field. His achievement of the latter was evidenced by an award of a "star" in the third edition of "American Men of Science." Entering high school at the age of twelve in Attleboro, Massachusetts, he took the college preparatory course which included Latin, Greek, French, algebra, geometry and history. He had early shown a talent in drawing and so spent his Saturdays taking drawing lessons and also lessons in German. Through the Superintendent of Schools, who was an enthusiastic amateur astronomer, Lamb and some of his chums followed the same fascinating route. The little group specialized in double stars and tried to spot all which could be resolved by their eight-inch instrument. When the parents of the little group rebelled against the midnight and early morning hours, Lamb's interest turned to microscopes. He finally bought the more difficult parts from Bausch and Lomb and constructed a microscope of his own in the tool-room of his father's jewelry factory. The making of the microscope showed him a lot about tools and metal-working techniques, and its

use opened his eyes to the multifarious and beautiful life in the streams and ponds of the countryside. During his high school years Lamb's keenest formal interest was in mathematics. He was one of those rare individuals who does mathematical problems for the fun of it. He even dabbled in constructions for trisecting an angle and for laying out a regular pentagon. Although he took no regular science course in high school, he spent some spare time with the introductory portions of the four volumes by Roscoe and Schorlemmer, the only chemistry work in the school library. He also worked a little in the physics laboratory after hours. On being quizzed on his science activities in high school, Lamb admits that the only experiment he remembers is the measurement of the surface tension of water by the drop-weight method, but he can not recall what led him to carry out this unusual experiment. His senior year corresponded with Roentgen's discovery of x-rays. He and his friends combined a small Crookes' tube and a frictional electric generator and were able to take a shadow picture of a key placed against a box containing a protected photographic plate.

At sixteen, Lamb entered Tufts College and quickly became interested in biology probably because of his knowledge of the microscope and his skill at drawing. He stayed with biology through his Bachelor and Master's degrees. His thesis for the latter was on the eye muscles of the common dog fish (*Squalus acanthias*). This was his first published article. During his college years, he continued his interest in mathematics, going through quaternions and the Newtonian Potential Theorem. He

<sup>1</sup> Awarded by the New York Section of the American Chemical Society, to the author or authors of the best paper "on the science or practice of chemistry." Investigators are eligible who have published original contributions in any of the publications of the American Chemical Society, or those under its auspices, during the three years preceding the presentation meeting.



THE WILLIAM H. NICHOLS MEDAL

also took practically all of the courses in chemistry which were offered. He finally decided to move into that field. During his senior year he had started work with Arthur Michael on a small research problem in inorganic chemistry on iodine oxides. He soon changed to Michael's major interest, organic chemistry, and studied the isomerism of the coumaric acid. While Michael was away for a year Lamb continued his research and taught two of his advanced courses. As a side line he was continuing his interest in biology and published a short paper on the "Mechanics of Mitosis." He also

spent a summer at the Marine Biological Station at Harpswell and succeeded in repeating with the sand dollar the brilliant experiment of Jacques Loeb on parthogenetic development.

After receiving the Master's degree Lamb decided definitely to go into chemistry, and into physical chemistry at that. Meanwhile he continued his work in organic chemistry. Although he had originally planned to go to Johns Hopkins University his decision was changed by his meeting Theodore William Richardson. He went to Cambridge and concentrated on physical chemistry.

Before transferring to Harvard, Lamb had completed all of the work for his Ph.D. in organic chemistry at Tufts under Arthur Michael, except for taking the final oral examination. He finally took in the same year the Ph.D. in organic chemistry from Tufts and the Ph.D. in physical chemistry from Harvard, a unique demonstration of versatility. The combination with a Master's degree in zoology makes the achievement even more remarkable.

Lamb then went to Europe for a brief period to study in Leipzig, Heidelberg and Goettingen. He then returned to Harvard for a year as instructor and then went to New York University, where he stayed until 1912 and became Director of the Laboratories. The latter year he returned to Harvard, where he has stayed continuously except for the period of the first World War which he spent in Washington.

Early in 1917 Lamb undertook some work for the Military Intelligence Department in Washington on secret writing. He soon took up work on the removal of carbon monoxide from air. This work was done in collaboration with the late Charles R. Hoover, of Wesleyan University, who lost his life in the present World War. They eventually developed a detector for carbon monoxide which they named "Hoolamite." It is interesting that it contained iodine pentoxide, one of the substances on which Lamb had worked as an undergraduate with Michael. Late in 1917 Lamb took leave-of-absence from Harvard and became head of the Defense Section of what was to become the Chemical Warfare Service Research Unit at the American University in Washington. He was commissioned a Lieutenant Colonel in the C.W.S. A large and effective organization was soon built up. One of the most important achievements of the group was the development of the catalyst for the conversion of carbon monoxide in a gas

mask into harmless carbon dioxide. This was carried out by workers from Johns Hopkins University and the University of California. The catalyst was finally called "Hopecalite" in honor of the two universities.

After the Armistice, Lamb went through a serious period of decision as to his future activities. At one time it seemed that he should continue as head of the Research Division of the Chemical Warfare Service. He also received tempting offers to head research organizations for some of the largest corporations in the country. He finally decided, however, to return to Harvard. Before doing so he served briefly as director of the Fixed Nitrogen Laboratory in Washington during the important period of its organization.

While Lamb's list of scientific publications is an imposing one and is characterized by unusual diversity, his greatest achievement in science will undoubtedly stand as his editorship of the *Journal of The American Chemical Society* which he has held since 1917. Under his charge this has become the greatest chemical journal in the world.

In 1940 Lamb was appointed dean of the Graduate School of Arts and Sciences of Harvard University.

Along with his busy life he has found time to serve as a valued consultant to many large chemical industries and has achieved an outstanding position as a chemical expert in many important patent litigations. He has received practically all of the honors and recognitions which can come to an American chemist, including membership in the National Academy of Sciences and the presidency of the American Chemical Society.

On the human side, Lamb is one of the most robust and virile of men and yet withal as kindly and friendly an individual as one can ever hope to know.

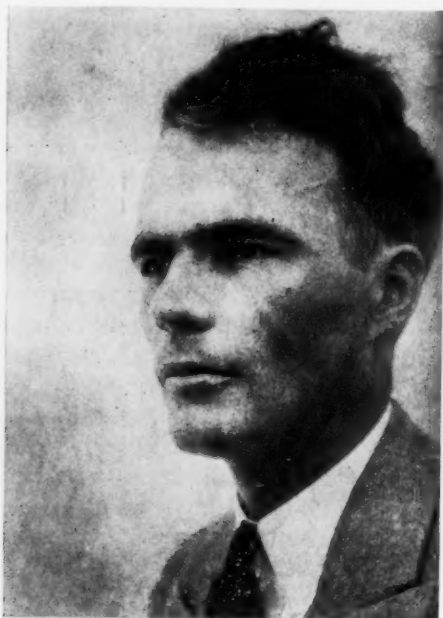
F. C. WHITMORE

## MEDALISTS OF THE NATIONAL ACADEMY OF SCIENCES

At its eightieth annual meeting the National Academy of Sciences awarded five medals to workers for extraordinary contributions to progress in certain fields of science. This custom of bestowing a medal upon an individual as a tangible recognition of an important accomplishment is an old one; originating with the armed forces in ancient times to commemorate acts of valor, it has gradually been adopted by national organizations to honor individuals for high achievements in various branches of human endeavor. Within each organization special trust funds have been set aside to encourage activity in special fields. Each trust fund is administered by a special committee charged with the responsibility of recommending to the organization candidates for the honor. Upon formal action by the organization the medal is awarded and then bestowed at an appropriate time.

The National Academy of Sciences follows this procedure and bestows medals on the occasion of the annual dinner, at which the president ordinarily speaks on the status of the Academy and on the aid it has rendered to the government in problems on which advice has been asked. Under present war time conditions the major part of the activity of the Academy is restricted to government problems, upon which general reports are made at closed sessions of the Academy, thus relieving the president of the need for the usual statement of progress.

At the annual dinner this year attendance was limited because of catering difficulties, to Academy members and medalists. President Jewett in his opening remarks described briefly the five medal awards and the trust funds from which they were derived. The medals were then bestowed in the order of estab-



DR. IRA SPRAGUE BOWEN  
PROFESSOR OF PHYSICS, CALIFORNIA INSTITUTE  
OF TECHNOLOGY.



*Harris & Ewing*  
COLUMBUS O'DONNELL ISELIN, II  
DIRECTOR OF THE WOODS HOLE OCEANOGRAPHIC  
INSTITUTION.

*Bachrach*

DR. EDWIN H. COLBERT

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY,  
AMERICAN MUSEUM OF NATURAL HISTORY.*Blackstone*

DR. ROBERT CUSHMAN MURPHY

CURATOR OF OCEANIC BIRDS, AMERICAN MUSEUM  
OF NATURAL HISTORY.

ishment of the trust funds. In each case the president called upon the chairman or representative of the committee which made the recommendation to present the candidate and to state briefly the reasons for the selection.

#### *The Henry Draper Gold Medal*

The Henry Draper Medal was awarded to Dr. Ira Sprague Bowen, professor of physics, California Institute of Technology, "in recognition of his contributions to astronomical physics; more especially his researches on the spectra and chemical composition of the gaseous nebulae." The presentation speech was written by Dr. J. H. Moore, of Lick Observatory, chairman of the committee on the Henry Draper fund; in the absence of Dr. Moore, it was read by Dr. S. A. Mitchell. To quote the first paragraph of this speech:

More than three-quarters of a century ago, Huggins, a former Draper medalist, found that

the spectra of certain nebulae were composed of sharp isolated bright lines, thus proving that their luminous material is a glowing rarefied gas. Some of the lines were recognized as those of hydrogen, and, later, others were identified as due to helium and ionized carbon, oxygen, and nitrogen; but nearly half of the nebular radiations, including the two strong green lines, could not be matched in any terrestrial source. These mysterious radiations were believed to indicate the presence in the gaseous nebulae of an unknown element "nebulium" and for more than sixty years the nature of "nebulium" remained one of the outstanding problems of physical astronomy with which the ablest spectroscopists had struggled and had failed. It was solved not by an astronomer but by a physicist, Professor Ira Sprague Bowen, of the California Institute of Technology.

#### *The Alexander Agassiz Gold Medal*

The Agassiz Medal with honorarium was bestowed upon Columbus O'Donnell Iselin, II, Director, Woods Hole Oceanographic Institution, "for his studies of the Gulf Stream system, for his leadership in the development of a general

program of the physical oceanography of the North Atlantic, and for his distinguished direction of the activities of the Woods Hole Oceanographic Institution, both in peace and in time of war." The presentation speech was made by Dr. Thomas Barbour, member of the Murray Fund Committee which recommended the medalist. In his talk Dr. Barbour recalled incidents in the life of Alexander Agassiz after whom the medal was named by Sir John Murray, donor



*Backrach*

DR. EDWIN G. CONKLIN

DEPARTMENT OF ZOOLOGY, PRINCETON UNIVERSITY.

of the Murray Fund. In the words of Dr. Barbour, "I wish to put on record the fact that I can think of no one who could stand as recipient and be more utterly satisfactory to Mr. Agassiz as him whom we honor now."

#### *The Daniel Giraud Elliot Medal*

The Daniel Giraud Elliot Medal for the year 1935 was bestowed upon Dr. Edwin H. Colbert, of the American Museum of Natural History, in recognition

of the high merits of his work "Siwalik Mammals in the American Museum of Natural History," published in the Transactions of the American Philosophical Society in 1935. The medalist was presented by Dr. Wm. K. Gregory, a member of the Daniel Giraud Elliot Fund Committee. Dr. Gregory emphasized the importance of the work of Dr. Colbert on the fossil mammals of India; in this field much work has been done during the past century. Dr. Gregory stated that in Dr. Colbert's "detailed analysis on the migration of certain mammals to and from the Siwaliks, we see India as at the crossroads, exchanging mammals with Europe and Africa on the one hand, and with Asia and North America on the other."

#### *The Daniel Giraud Elliot Medal for the Year 1936*

The Daniel Giraud Elliot Medal of 1936, with accompanying honorarium of \$200, was given to Dr. Robert Cushman Murphy of the American Museum of Natural History in recognition of the importance of his work on "Oceanic Birds of South America" published in two volumes in 1936. The presentation speech was written by Dr. Frank M. Chapman; in his absence, it was read by Dr. Ross G. Harrison, former chairman of the committee on the Daniel Giraud Elliot fund. Dr. Chapman emphasized the long period of training had by Dr. Murphy in preparation for his monograph of 1,245 quarto pages on the subject. He spent several years in various regions of South America and when, later, the collection of 7 853 ornithological specimens, gathered by R. H. Beck during four and one-half years, reached the American Museum, Murphy, in the words of Dr. Chapman, "was the one man qualified by experience, training, and desire to interpret this collection. With most of the species represented, he was familiar in life; and he had visited a large part of the area, whence they

came. Thus his field studies, added to Beek's collections, made the ideal laboratory combination.

"To the systematic treatment of all forms concerned, there was added an exposition of Murphy's discovery that oceanic birds are subject to the same kind of environmental control as seals, sea-turtles, and even fish. The part played in distribution by the temperature of water as well as air, the influence of wind and of currents, and the effects of insular isolation are also considered. Full biographies, when available, are given with each species, and long-standing biologic problems like that presented by the confusing relations of the steamer ducks are satisfactorily treated."

#### *The John J. Carty Medal*

The John J. Carty Medal with accompanying honorarium was bestowed upon Professor Edwin G. Conklin of Princeton University under the citation: "Zoologist, Cytologist, and Embryologist; Philosopher, Teacher, and Scientist; student of life and of growth from lowliest beginnings to highest consummation." The presentation speech was made by Dr. O. E. Buckley, chairman of the committee on the John J. Carty fund. In it he referred especially to the friend-

ship between General Carty and Dr. Conklin and to the influence the one had on the other, especially of Conklin's philosophy on Carty's thinking. In the words of Dr. Buckley:

Conklin has pointed out that man's future development lay not in the evolution of man as an individual but in the evolution of society—the building of an harmonious body out of cooperating human elements, with man adding to his own power the forces of nature. Carty saw in the telephone system of his creation the nerve system of that society—his telephone wires and radio channels were the nerves to provide communication among the specialized human elements of the peaceful and efficient social organization yet to be evolved.

In gratefully accepting the medal and award, Professor Conklin expressed great surprise and pleasure that he should have been chosen as the recipient. He appreciated thoroughly the act of the committee which had thus associated his name with that of General Carty, whom he had known for many years and had greatly admired and respected. He mentioned the discussions he had with General Carty on many subjects, and the stimulus he had derived from them and from the impact of General Carty's personality.

F. E. WRIGHT,  
*Home Secretary*

#### POWER FROM PULVERIZED COAL

POTENTIAL reductions in the approximately two million barrels of fuel oil used annually by the forging industry by its replacement with pulverized coal are shown to be possible in a recent survey made for Bituminous Coal Research, Inc., by Battelle Memorial Institute, Columbus, Ohio. This has focussed renewed attention on pulverized coal—its history and its utilization.

As the world's principal source of heat and power, coal is the very foundation of our present industrial civilization. World consumption is about one

and one half billion tons annually, and there is little doubt that coal, both in solid and in pulverized forms, will long continue to be the basic source of the country's energy requirements. Best estimates indicate enough bituminous coal to last this country 4,000 years at the present rate of consumption, or 2,000 years if all our present energy demands were to be supplied by coal.

Pulverized coal, sometimes also called powdered coal, is adaptable to many industrial uses. Coal in this form—any coal whose moisture content has been re-

duced and which subsequently has been ground to an extremely fine powder in special mills—has several advantages in certain applications.

#### *Work Began a Century Ago*

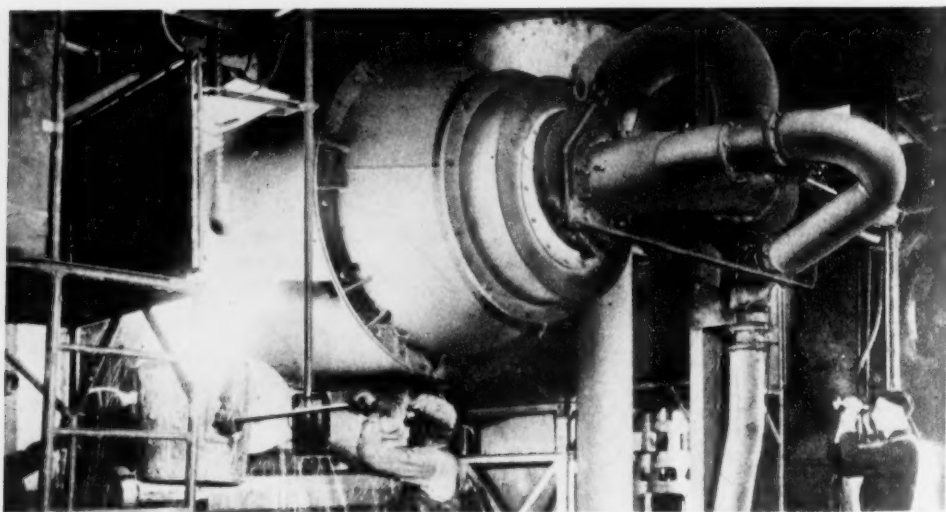
The technology of pulverized coal has been the object of study by engineers and scientists for more than a century. Experimental work conducted as early as 1831 by the Englishman, John Samuel Dawes, establishes him as an early pioneer in pulverized coal firing. However, to the Englishman, T. R. Cramp-ton, must go the chief glory of the pioneering period. In 1873 he read a paper before the British Iron and Steel Institute which expressed views which were fundamentally correct. The deductions that resulted from the five years of experimental work which preceded his presentation were unusually sound. He was strongly insistent on the importance of the size of the fuel particles and of the intimate mixture of air and coal. His experiments were concerned with the use of pulverized coal in steam boilers and puddling furnaces.

It is reported that the numerous failures which attended the early history of fuel applied in pulverized form resulted in some contempt and ridicule in engineering circles. The heavy deterioration of refractory linings, the rapid coating of boiler surfaces with an impervious insulating layer of ash slag, irregularity of fuel control, the constant fear either of spontaneous combustion or explosion, both of which frequently occurred in these early experiments, all combined to insure failure.

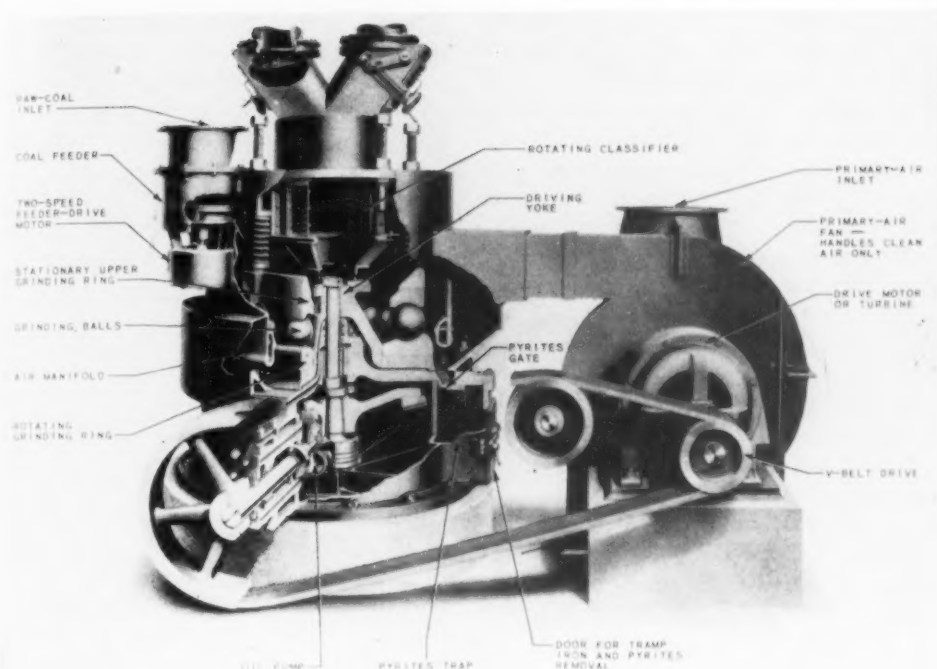
Faults were gradually overcome. By the turn of the century pulverized coal was being used successfully in rotary cement kilns, where its success has been so marked that it can be claimed to account for about eighty per cent. of the world's output of Portland cement. Its successful application to various metallurgical furnaces and stationary boilers occurred in the 1915-1925 period.

#### *Metallurgical Applications Varied*

Metallurgical applications of pulverized coal include its use in forge, melting, annealing, billet heating, piling, rever-



METALLURGICAL APPLICATIONS OF PULVERIZED COAL  
INCLUDE ITS USE IN ROTARY MELTING FURNACES, SIMILAR TO THE ONE SHOWN. THE CURVED PIPE  
IN THE FOREGROUND SUPPLIES THE COAL-AIR MIXTURE.



BALL-RACE PULVERIZER, WIDELY USED IN THE PULVERIZING OF COAL

laboratory and puddling furnaces, as well as the open hearth. In 1929 there were 200 pulverized fuel plants installed in the United States in connection with the iron and steel industry, and they served 2,500 furnaces which consumed 3,000,000 tons of bituminous coal annually. One Pennsylvania plant used pulverized coal from 1913 to 1939 as a fuel for melting steel in the open hearth furnace.

Although domestic heating units are the major sources of the smoke nuisance in large cities, the use of pulverized coal in metallurgical furnaces and for boiler firing can contribute to smoke abatement because of its smokeless combustion.

Since 1920, when the first large boiler in this country was successfully fired with pulverized coal, its use as a fuel for large steam boilers in industrial and public utility plants has accelerated. Today, pulverized coal is the predominant fuel for this use.

#### *Virtually Complete Combustion*

A lump of coal of one cubic inch, having six square inches of surface for exposure to burning, by pulverization may be reduced to upwards of 50,000,000 small particles, collectively presenting an assumed 2,000 square inches of oxidizable surface. If one visualizes the burning of lump coal on a grate, it is apparent that combustion passes through a number of phases, and the rate of combustion will depend on the rate at which the oxygen in the air can be brought into contact with the coal.

Coal in the lump usually is slow burning, but its rate of combustion can be accelerated greatly by the adoption of forced draft. Even so, unconsumed carbon sometimes remains in the ash and unburned fuel is carried to the stack. On the other hand, the minute particles of pulverized coal are discharged through a burner into the furnace complete with

the air required for complete combustion, and virtually perfect combustion can be obtained. Although at first thought it might appear that the pulverized coal would have a higher combustion rate, the rate is similar, per cubic foot of furnace volume, to that obtained with solid coal in stoker firing.

Furnaces are often fired directly from individual pulverizer mills with success equal to that attained by direct-fired steam boiler furnaces. However, it is often desirable to pulverize at a central plant and distribute the coal to individual furnaces. There are various ways of achieving this distribution. Pulverized coal when mixed with air can be made to flow through standard pipe over distances up to 5,000 feet, and the most common types of distribution utilize this property.

#### *Wider Utilization Foreseen*

Power directly from coal has long been the dream of engineers, and technologists at Battelle Memorial Institute, under the sponsorship of Bituminous Coal Research, are investigating this possibility along with other applications of pulverized coal.

As a further application, one writer has suggested that Germany may attempt to devise ways to utilize pulverized coal as an aircraft engine fuel because of her difficulty in retaining adequate supplies of petroleum. This recalls the interesting fact that when Diesel, about 1890, was planning the type of engine which now bears his name, his primary idea had been to employ coal dust as fuel. After several years of experimental work, the engine which he constructed proved to be adapted to oil fuel but not at all to coal or even gas, and so for this, as well as economic reasons, its ultimate development was directed toward the utilization of oil.

Although unsuccessful as a locomotive fuel twenty years ago, advances since that time indicate that pulverized coal will be an important locomotive fuel of the future. Anticipating further advances in coal science and technology, one may expect still wider utilization of this fuel of our ancestors by our progeny, and its advantages of complete combustion, perfect control and flexibility will contribute much to its expanded use.

R. O. STITH

#### HUNTING FOR GRANDPA BUMPS

THE Redbeds of Northwestern Texas, containing the remains of many ancient land vertebrates, have been worked for seventy years past. But until the discovery of Grandpa Bumps only one large ancient amphibian had been found in these deposits. This was *Eryops*, a rather advanced type, familiar to museum visitors and to readers of elementary texts. I was consequently much surprised when, a dozen years or so ago, I ran upon fragments representing a large new labyrinthodont. The material was very scrappy—bits of backbone and limbs and, most common, chunks of bone about the size of one's fist. These bore, on one surface, the pitted sculpture

common on the skull bones of early amphibians and on the other, the broken-off bases of very large teeth.

Obviously the animal was a new one, and since the remains were from a horizon lower than those normally worked in Texas, the chances were very good that it might be a more primitive form than those common in the Texas beds. The characteristic "nuggets" were surely representative of thickened swellings on the animal's muzzle which, because of their stout build, survived the vicissitudes which had destroyed the rest of the skull. It was therefore reasonably given the scientific name of *Edops*—"swollen face." To those of us who

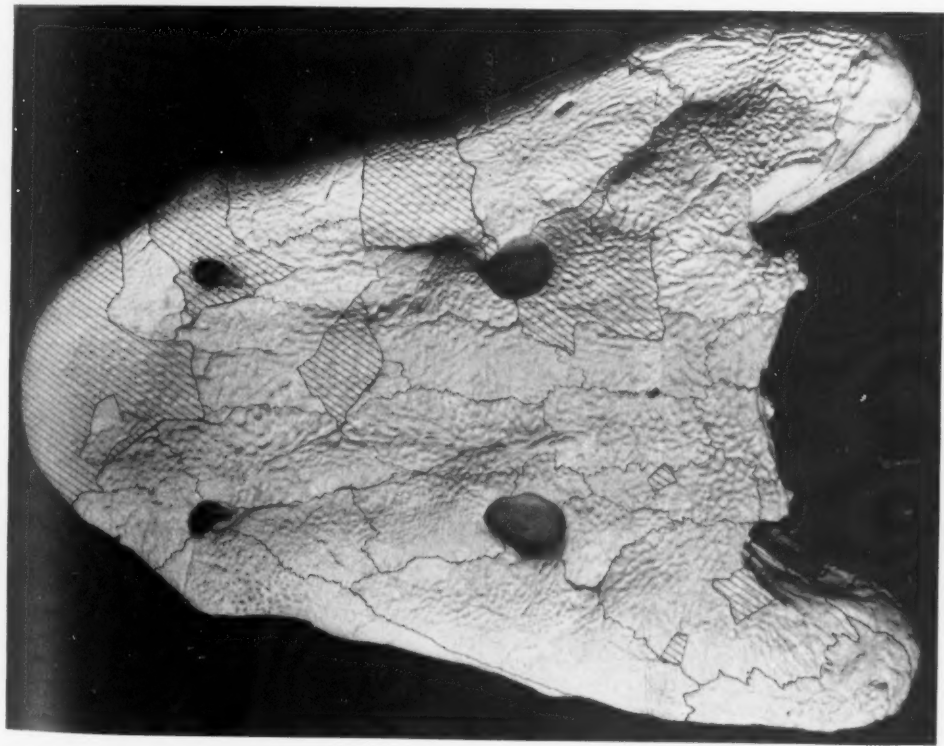
searched for his remains, however, the creature has been known by the more homely name of "Grandpa Bumps."

The first scraps found of Grandpa Bumps only whetted our appetites for more. We desired a skeleton, if possible, or at least a skull—for many of the most important features of amphibian evolution are revealed in cranial morphology. For some years he eluded us. More and more scraps were found, but never a skull or skeleton, or even any two pieces that would fit together.

Finally, one spring a few years back, when I found it possible to get to Texas for a month, and to take with me assistant preparator R. V. Witter, from the Harvard Museum, it was decided that our main purpose would be to trace Grandpa Bumps to his lair, and devote our energies to exploring the formation in which alone his remains were to be

expected. We did so; but it was a dreary business. The sediments of this horizon are unusually barren and many a day we would return to camp without a bone of any sort worth saving—and with no trace at all of our venerable amphibian friend.

Came the last day before I must take the train back to Cambridge. We had resigned ourselves to failure as regards Edops, and comforted ourselves in the thought that we had at least found a few other interesting specimens. That morning, as a last try, we stopped our car at Terrapin School. Behind the white schoolhouse the bank dropped sharply into a natural amphitheatre, perhaps a mile across. Its center was a flat mesquite-covered plain. But its margins, fifty feet or more high, showed plenty of rock surfaces in which fossils might be found. So at the bottom of the slope



RECONSTRUCTED SKULL OF EDOPS—"GRANDPA BUMPS"

we parted, Witter to work round the left side, I to the right, with the understanding that if all went as usual we would meet on the opposite side at lunch time.

On my side of the hollow I found plenty of clays and shales and gravels to be looked over, many a bank to climb and gullies to explore. But no trace of bone of any sort. It was a hot June day, with a temperature that was probably about 100° in the shade, and considerably over that in the white glare from bare rocks in the still air of this depression. By noon I had reached the far side of the hollow, weary, discouraged and thirsty, longing for a return to the shade of the car and a deep draught of canned tomato (civilization's greatest gift to the Southwest).

But Witter hadn't arrived. The task was not completed. So I kept on along the wall of the amphitheatre, looking (but not too hopefully) for bone and (hopefully) for Witter around each corner.

Two o'clock. Still no Witter. This was really too much. I abandoned the search and struck back across the flat and through the mesquite for the car.

There, not more than a hundred yards from our starting point, the missing Witter sat, cool and happy, fitting together pieces of bone. Within a few minutes of the time we parted he had come upon the place where the skull of a great amphibian, now broken into fragments, had lain. And he had spent the rest of the morning right there, searching for the pieces, large and small, which had washed away from the spot and been buried in the gravels and clays nearby. When such pieces as could be

readily fitted in the field were put together, we saw that we had a new type of amphibian skull—and that this new type was the long-sought-for Grandpa Bumps.

Grandpa returned with us to the laboratory. A few pieces of his skull (indicated by hatched areas on the accompanying photograph) had apparently washed too far down the gullies for us to find, but most of it was present, and except for the tip of his snout we were finally able to make out almost every feature of his cranial anatomy; the details are given in a paper by Witter and the writer in a recent number of the *Journal of Geology*. The skull is nearly a yard in length and is, as far as I am aware, the largest known among Paleozoic amphibians. More important is the fact that it proved, as we had hoped would be true, to be more primitive than that of the typical Redbeds labryrithodonts. Because of excellent preservation (as contrasted with the imperfections of Carboniferous material), Edops can thus boast of having the most primitive of adequately known amphibian skulls. From the well-preserved braincase it proved possible to obtain an excellent cast of the brain cavity. This has been described in the *Journal of Comparative Neurology* by Dr. Tilly Edinger and the writer. It appears to have enclosed a type of brain more primitive than that of any living tetrapod and offers valuable clues as to the course of brain evolution in land vertebrates. Grandpa Bumps was a modest and retiring animal; but at long last he did his bit toward the advancement of science.

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